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MMS 93-0013

Solid Waste Pollution on Texas Beaches: A Post-MARPOL Annex V Study

Volume I: Narrative

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MUSTANG ISLAND GULF BEACH

U.S. Department of the Interior
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Solid Waste Pollution on Texas Beaches: A Post-MARPOL Annex V Study

Volume I: Narrative

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1. INTRODUCTION

1.1 Objectives

Project MMS-Beach was designed to test the effectiveness of MARPOL Annex V in reducing the quantity of man-made debris littering Gulf of Mexico barrier island gulf beaches, specifically those in Texas. Annex V of the International Convention for the Prevention of Pollution from Ships, 1973 (MARPOL) became international law on 31 December 1988. The Annex prohibits the discharge of plastics into the ocean and limits the discharge of other solid waste pollutants within varying distances from the U.S. coastline. The U.S. Minerals Management Service (MMS) needs to know if users of the Gulf of Mexico are observing Annex V. If so, then this should manifest itself in a reduction in the quantity of certain types of litter found on Gulf beaches. These materials include those readily identifiable with various operations of interest to MMS, for example, items from the offshore oil and gas exploration and production industry. The objective of this study was to compare results of beach-debris surveys done two years after, with those done two years prior to Annex V entering into force. The methods of surveying the beach had been devised by the author and were to be repeated in the post-MARPOL Annex V period.

1.2 Background

The investigator started looking at litter on Mustang Island (Texas) gulf beach (Figure 1.1) in 1978 when a survey was initiated to monitor the bird population with the advent of beachfront development. At first the references to litter and debris were anecdotal, in the form of notes and sporadic measurements. In 1983 an attempt was made to estimate the quantities of both man-made and natural debris using some 40 categories of debris types. Estimates were based on the investigator's knowledge of the common items after five years and over 500 observations to that date. An index system was devised based on a 0 to 5 scale of magnitude. This method is still employed on the survey (now with 2,100 observations) and is useful in gauging the seasonality of materials washing up on the beach, especially in some categories.

This method does not yield quantitative data (although curves have been fitted to some common items after numbers were counted independently and graphed against the estimates). The counts were started in 1987 with some financial assistance from the Texas A&M University Sea Grant Program. In addition to the beach-bird surveys (BEACHobs), special garbage surveys (GARBGobs) covering the same 11.8-km stretch of beach were done at an eight-day interval. Items large enough to be seen from a slowly moving vehicle are counted; about a hundred categories of litter and debris are logged. It was on the basis of this study, done in 1987 and 1988 before the enactment of MARPOL Annex V (in force 1 January 1989), that the investigator proposed to MMS to repeat this survey some two years after MARPOL Annex V.

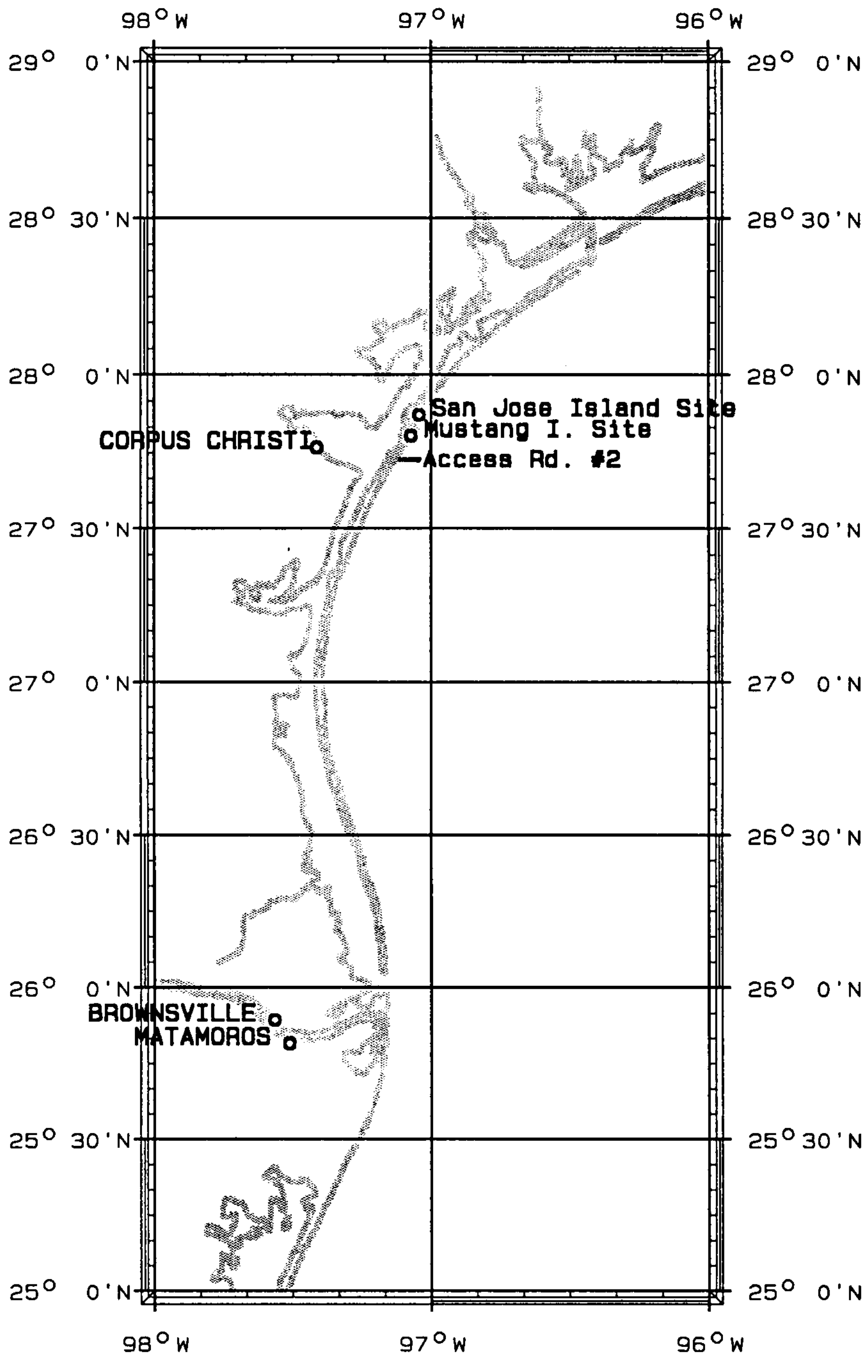


Figure 1.1. Location Map of Study Sites.

This report contrasts the "before" and "after" data to see if there is any indication that MARPOL has affected the littering of Texas beaches.[1] A direct link between Annex V and changes in litter on beaches cannot be forged. However, looking at the nature of the debris items before and after MARPOL may give clues to its successful implementation and adherence to by seagoing vessels. This survey is referred to as the "Weekly Counts". About 200 such counts were made, 175 of which are used in this report (the others were special counts done in conjunction with National Cleanups and other events).

To examine smaller items, another survey called "Weekly Collections" was made in 1987-88 and repeated in 1991-1992. All debris and litter items were collected from three sites in the same beach area at the same time that the counts were done. Sites were 10-m wide and stretched from the shoreline to the high-tide line. This study was designed to quantify the smaller litter items and the "uncountable" natural debris items such as seaweed and tar.

After 1988 the arduous GARBGobs counts were continued sporadically through 1990. So as not to lose the continuity of data gathering, selected easily counted items were added to the BEACHobs bird counts and done on a bi-daily schedule. These are called the "Count of Five" for the five targeted items.

Finally, to identify sources of marine debris in detail, we made monthly collections of all containers on San Jose Island to the north of Mustang Island. San Jose Island is inaccessible except by boat and there is no cleaning of its gulf beach.

2. METHODS

2.1 Weekly Counts

An 11.8-km stretch of Mustang Island gulf beach (Figure 2.1) is surveyed by automobile at regular intervals to determine the debris and litter load by counting. At dawn, the vehicle is driven slowly down the beach from north to south, just shoreward of the last high-tide line. The criterion for choosing various items to count was their "countability" from a slowly moving vehicle and the actual experience with the method gained in the several years of observations prior to 1987. In general, items must be large enough to be seen from the truck. This eliminates what I call the "micro-trash" (e.g. small pieces of styrofoam, plastic beads, cigarette butts). Some 84 categories were counted during the GARBGobs surveys (Table 2.1). Two, often dominant, but uncountable items (*Sargassum* weed and tar) were also sampled along with the microtrash during the weekly garbage collections.

Items are counted individually or in groups when numbers require block-counting. Generally, only litter and debris items seaward of the latest high tide line are counted to minimize recounting items that can remain on the beach from one survey to the next. People, and some "beachgoer" items such as beverage cans, are counted wherever they are on the beach. For debris counting, the early start is chosen because beach cleanup crews from the City of Port

[1]It was widely believed that Annex V would take several months, perhaps years, to make an effect on the dumping of plastics at sea and reduction of litter on the beaches. In this report, the "before" and "after" dividing line is taken as the date that MARPOL went into effect (31 December 1988). In Appendix B a comparison is made with some of our data using 1 January 1990 as the dividing line.

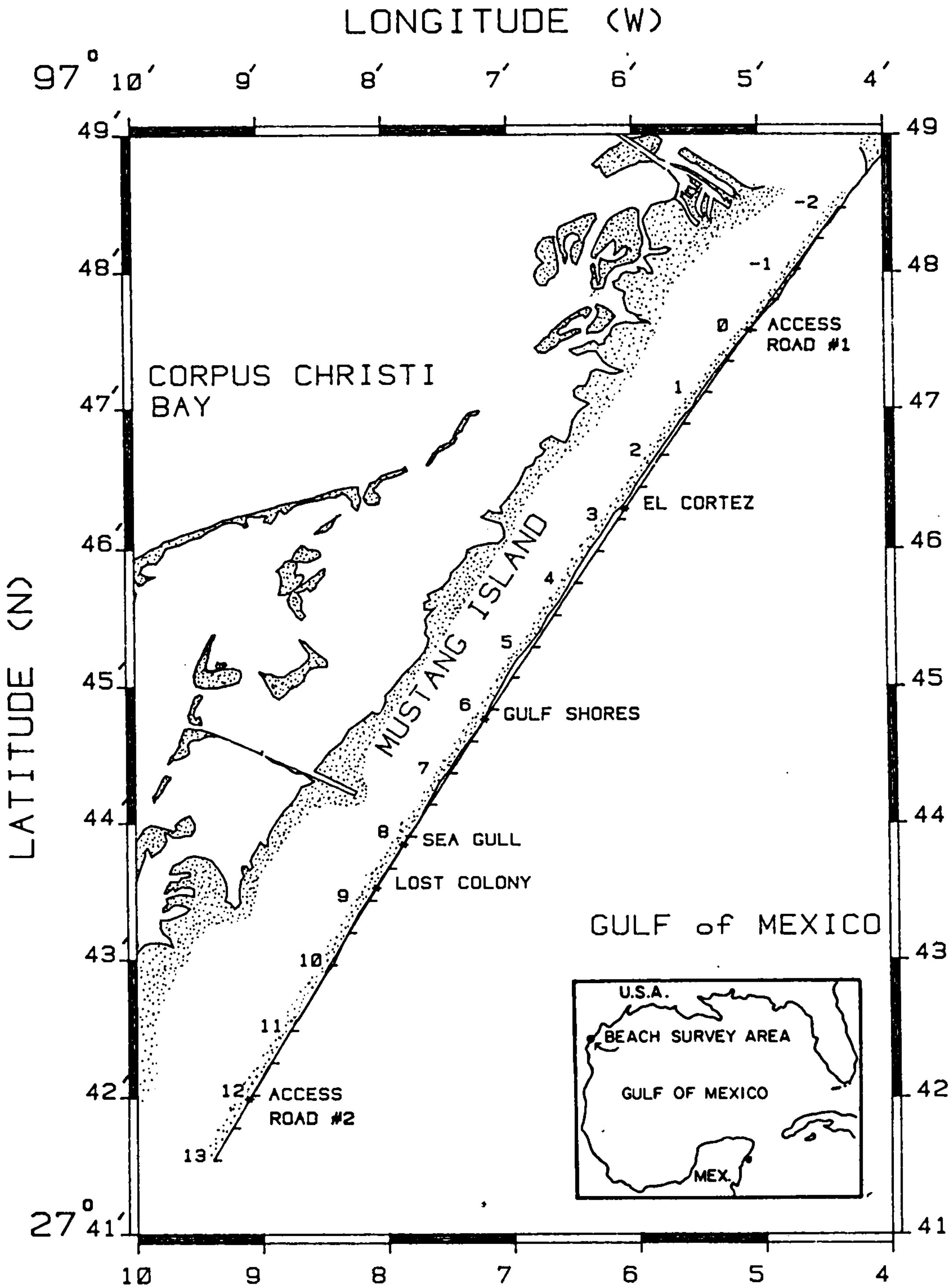


Figure 2.1. Mustang Island, Texas: Details of Survey Site

Table 2.1: Weekly Debris Count Codes (1987 - Present)

Programming and Computer Indices

Code	Item	Brief Explanation
OBS#	Observation Nunber	-
JULN	Julian Day	Starting 12/01/78
STRT	Start Time	-
TIME	Time of Observation (Min)	In Minutes and 1/10ths
DIST	Distance of Observation	In Miles and 1/1000ths
TOTL	Total Number of Items	-
TYPE	Number of Types of Debris	-
KILO	Number of 30-Sec Km Marks	From Electronic Odometer

General Debris and Litter Categories

Code	Item
HUMN	People-Related Activities
NATL	Natural Debris
FSHG	Fishing Industry
OILI	Offshore Oil Industry
MRCH	Merchant Marine
GALY	Galley Waste
MISC	Miscellaneous Stuff
BCHG	Beachgoer Litter

People-Related Activities

Code	Item	Brief Explanation
CARS	Automobiles	Driving or Parked
PEOP	People	Day Beachgoers (Also in Cars)
DOGS	Dogs	Loose, Feral or on Leash
HORS	Horses	Nearby Stables
CMPC	Camped Cars	Parked Overnight Camping
CMPP	Camped People	Overnight Campers
CTOT	All Cars	Total of CARS+CMPC
PTOT	All People	Total of PEOP+CMPP

Natural Debris

Code	Item	Brief Explanation
PMOW	Portuguese Man-o-war	*Physalia physalia*
CAB	Cabbagehead Jellyfish	*Stomolophus*
DBRD	Dead Bird	
DRFT	Driftwood	
INJD	Injured Bird	
DEAD	Dead Bird	
PENS	Pen Shells	*Atrina*
BEAN	Sea Beans	
COCO	Coconuts	

Table 2.1 (Continued)

Fishing Industry

Code	Item	Brief Explanation
FLOT	Floats	Fishing & Seismic Research
NETS	Fishing Nets	Gill, Cast and Shrimp Nets
LINE	Fishing Line	Monofilament Pieces
STIK	Light Sticks	Used in Longline Fishing
TRAP	Crab and Other Traps	Used by Fishermen
FISH	Dead Fish	Shrimp By-catch, Surf Fishing, Fishkills
CRAB	Dead Crabs	Shrimp By-catch
SACK	50-Lb Woven Plastic Sacks	Shrimper's Frozen Catch
GBOT	Green Bottles	Mexican Bleach Bottles
GLOV	Gloves	Rubber/Plastic; Shrimping Use
2STR	Two-Stroke Oil Bottles	Outboard Motors
REEL	Reels	Cable, Fishing Line
SRMP	Shrimpboats	Seen Offshore During Obs

Offshore Oil Industry

Code	Item	Brief Explanation
PLAS	Plastic Sheeting	Large Heavy-Gage Pieces
STRP	Plastic Strapping	Used in Shipping Boxes
RING	Mag Tape Write-Protect Rings	Seismic Survey Use
HARD	Hardhats	Head-wear
55GL	55-Gallon Metal Drums	Oil and Chemicals
CARB	5-Gallon Carboys	W/Spouts; Chemical Containers
PAIL	5-Gallon Plastic Pails	W/Lids; Oil/Chemical
PALL	Wooden Pallets	Used in Shipping
WIRE	Wire and Cable	-
LUBE	Tubes of Grease	-

Merchant Marine

Code	Item	Brief Explanation
BROO	Brooms	From Ships at Sea
BULB	Lightbulbs	Regular and Mercury/Sodium
FLOR	Flourescent Light Tubes	-
DUNG	Dunnage	Wooden Structure Used in Shrimping
CRAT	Wooden Crates	Produce and Shipping Crates
CART	Cardboard Cartons	-

Galley Waste

Code	Item	Brief Explanation
MILK	One-Gallon Milk Jugs	Incl. Drinking Water Jugs
EGGC	Egg Cartons	Styrofoam; Usually 1-Doz Size
GARB	Garbage Bags Full of Garbage	Need I say More
OCAN	Other Than Beverage	Spray/Food/Paint
FRUT	Fruit	Citrus Fruits

Table 2.1 (Continued)

Galley Waste (continued)...

VEGS	Vegetables	Onions, Melons, Greenstuff
GLAS	Glass Bottles	Liquor, Softdrink, Household

Miscellaneous

Code	Item	Brief Explanation
PBOT	Plastic Bottles	All Types
PMSC	Miscellaneous Plastic Pieces	Other Than Styrofoam
METL	Miscellaneous Metal Pieces	All Types
STYR	Styrofoam	Other Than Floats
FOAM	Foam (Except Styrofoam)	Packaging
PBAG	Plastic Bags	Mainly Polyethylene
APPL	Large Appliances	Refrigerators, Stoves, etc.

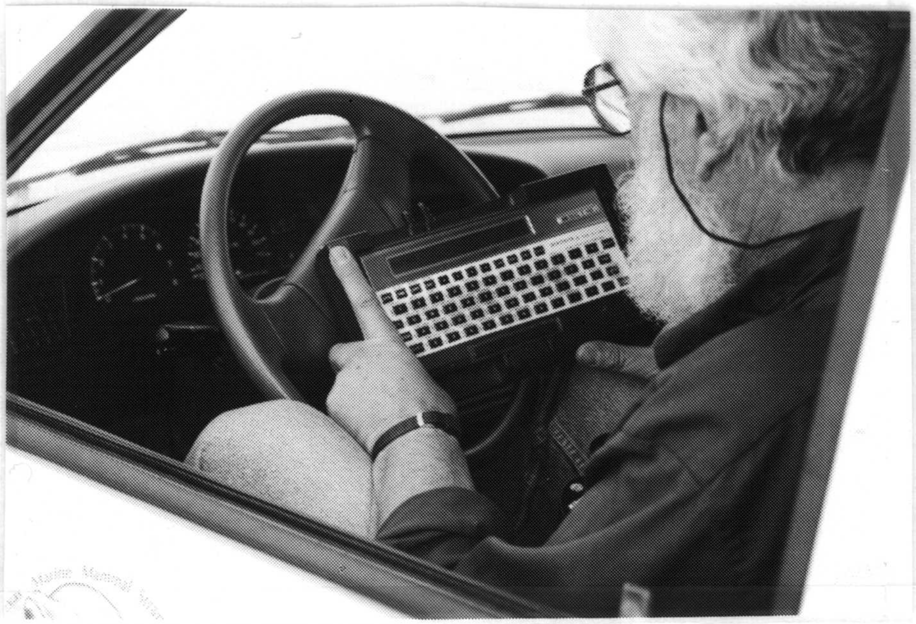
Beachgoer Litter

Code	Item	Brief Explanation
BEVG	Aluminum Beverage Cans	Softdrink/Beer
6PAK	Six Pack Rings	From Softdrink/Beer Packs
LGHT	Disposable Lighters	-
FIRE	Spent Fireworks	-
CUPS	Disposable Drink Cups	-
LIDS	Plastic Lids	-
TABS	Pull-Tabs	From Beverage Cans
CAPS	Bottle Caps	-
DIAP	Diapers	Disposable
CLTH	Cloth and Clothing	-
HAT	Hats (Other than Hardhats)	-
SHOE	Shoes	All Types
PAPR	Paper Products	-
BAGS	Paper Bags	-
NEWS	Newspapers; Magazines	-
BALO	Balloons	-
TOYS	Toys	-

Aransas, Nueces County and those hired by the condominium owners usually start their jobs later in the day. Also, for much of the year, air temperatures and humidity on a South Texas beach make lengthy observations in a slowly moving vehicle very uncomfortable as the day progresses. Driving south provides the least amount of glare from the sun for most of the year. A Hewlett-Packard HP75C hand-held computer with 24-KByte memory is used to record the data on the beach (Figure 2.2). A program (GARBGobs) has been written in HP Basic to permit the entry of data, notes and other pertinent information. To conserve memory, each type of item counted is represented by a single ASCII character. In this way, some 240 (some of the 256 ASCII codes must be reserved for normal computer operation) separate "species" can be represented in memory by a single byte. The keys are reconfigured and a special template used to allow single-keystroke entry of items observed (Figure 2.3). The numerical keys are left unconfigured so that items seen in groups can be entered by pressing the appropriate key followed by the number of items seen. To permit the entry of notes, pressing the "NOTES" key unconfigures the keyboard, reverting it to a regular QWERTY keyboard.

At the end of each survey while still on the beach, the program displays the totals of every category of items counted to alert the operator of any obvious errors. Back in the laboratory, programs are used to dump the data to a Hewlett-Packard 150 PC for permanent archiving on disk. Three disk files are saved: the raw data with distance information imbedded, the notes with appropriate codes, and the totals file. Other programs print the data in a readable form for a hard-copy record, and in an abbreviated form for pasting in notebooks. Thus redundancy is maintained for storage of the final data.

A NuMetrics distance processor and RS-232 interface is connected to the truck's transmission and provides continuous output of distance travelled while the survey is in progress. At 30-second intervals, the GARBGobs program interrogates the NuMetrics and automatically outputs distance (in meters) to the HP75. Whenever the vehicle is stopped to take notes or examine a particular item, distance is output to the computer. Thus the location of items as well as the grouping and numbers are acquired during the survey. Table 2.1 lists the categories and their ASCII codes, grouped under headings indicating their use by the program or probable source. Debris collections and counts are confined to the width of beach bounded at the time of observation by the shoreline and the high tide line. On the study beach, this can vary from near zero to 40 m or more. The width is measured using a surveyor's wheel for each survey and at each of the three sites. Local weather, sea and beach conditions at the time of the surveys are measured in an attempt to relate the observed incidence of debris and litter with those physical forces that can be responsible for its beaching. Sea temperature in the surf zone is measured with a deep-sea reversing thermometer and a salinity sample collected which is later analyzed using a laboratory salinometer. Other environmental data are obtained in real-time from a NOAA/ U.S. Weather Service Coastal Marine Automated Network (C-MAN) station located on Horace Caldwell Pier, about three miles north of the study beach. Before each survey, a program is started on a laboratory PC computer to interrogate the C-MAN via a telephone modem each hour on the hour. Data obtained includes winds, air temperature, barometric pressure, sea temperature, and tides.



(a)

(b)

Figure 2.2. Survey Vehicle and Equipment: (a) HP-75 Computer in Use and (b) HP-75 Computer and Electronic Odometer and Interface.

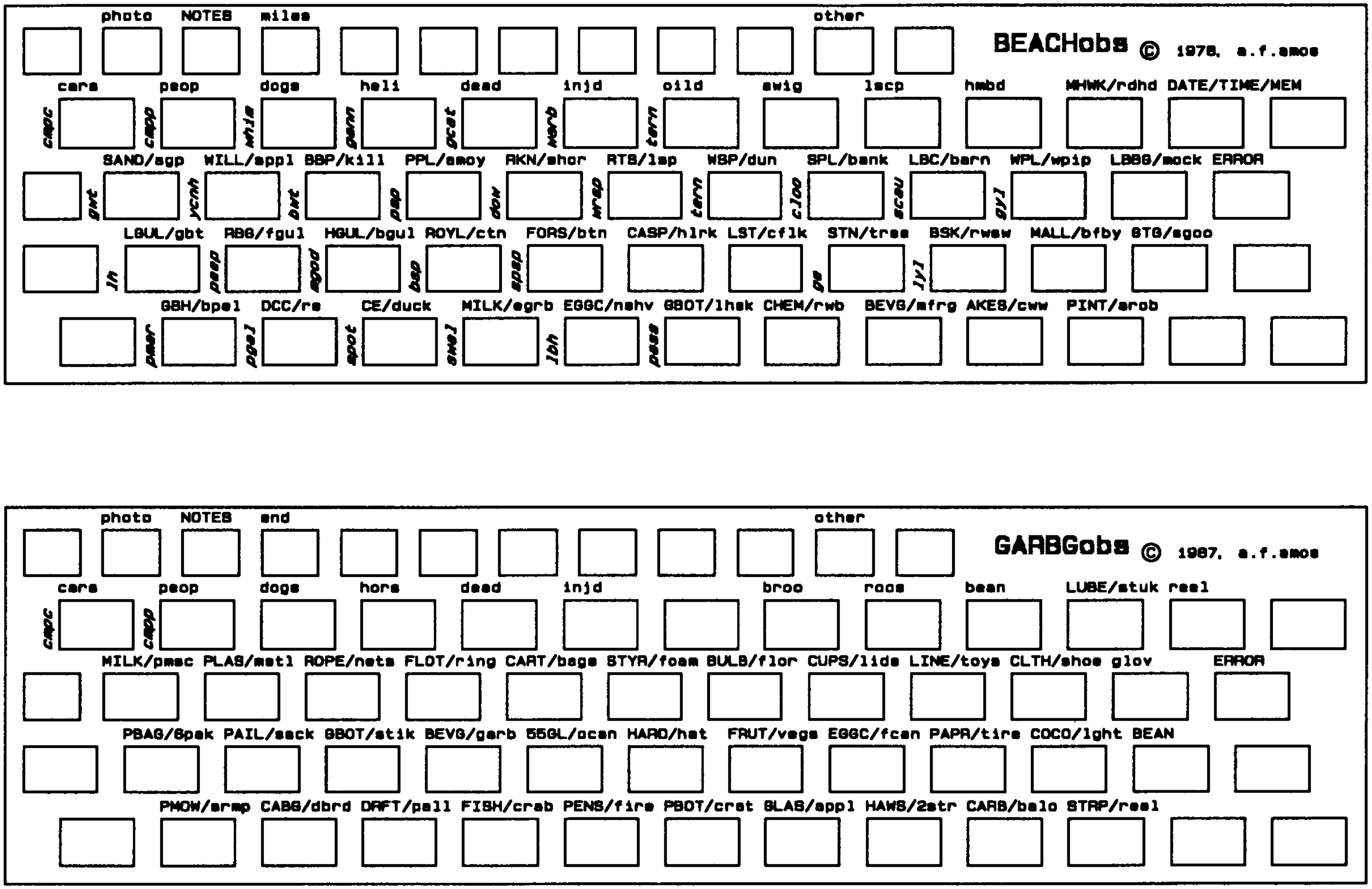


Figure 2.3. GARBGobs and BEACHobs Templates for the HP-75 Computer.

2.2 Bi-Daily Count of Five

In 1988, I started counting selected litter items during my bird survey of the same stretch of beach covered by the MMS-Beach survey. These surveys are done on alternate days. Five categories of litter were chosen because they were easy to see from the moving vehicle and were each representative of a particular source (Table 2.2). The first two items, **MILK** (one-gallon plastic milk and water jugs) and **EGGC** (plastic egg cartons) probably have the same source: the shrimp boats, longline fishing boats and other small craft that spend more than one day offshore and are locally based. **CHEM** (drums, carboys and pails) are usually empty when found on shore and bear labels that indicate their use by the offshore oil and gas exploration, drilling and production industry. The majority are 5-gallon in capacity, but each year several 55-gallon drums wash ashore here. **GBOT** (green bleach bottles) are plentiful at certain seasons; they are small-volume (1 liter or less) plastic bottles of the popular household bleach brands sold in Mexico. Their presence on the beach is an indication that the nearshore currents are coming from the south. **BEVG** (beverage cans) discarded by visitors to the beach are indicators of beachgoer activity, although some are seaborne from the recreational boating and fishing industry.

Table 2.2: Litter Items Counted During Bi-Daily BEACHobs (1987 - Present)

#	Code	Item Counted	Brief Explanation
89	MILK	One-Gallon Milk Jugs	Galley Waste From Shrimpers and Other Small, Local Fishing Vessels
100	EGGC	Plastic Egg Cartons	As Above
162	CHEM	Drums, Pails, Carboys	Containers of Chemicals Used by the Offshore Oil Industry
151	GBOT	Green Plastic Bottles	Bleach Bottles From Mexico; Possibly Used by Shrimpers, But Indicator of Currents From the South
204	BEVG	Beverage Cans	Main Source is From Beachgoers

The relationship between these items and the industry sources is one which the author has established by enquiry and deduction. It is not easy to obtain direct confirmation from industrial sources on the types of disposable materials used at sea peculiar to that industry. This is especially true of the shrimping and Mexican sources. Because of distrust of "authorities" and apprehension of possible legal action against them, the target industries are reluctant to reveal details of their provisionage. Some items are unmistakably related to particular industries. The pathways by which they leave the land where they are purchased and return to the beach via the sea are often not knowable.

2.3 Weekly Collections

These collections are done every eight days to determine the association of man-made litter with naturally occurring seaborne debris, to examine the nature of the "micro-trash" that is not countable, and to compare the efficacy of the counting method. Three 10-m wide transects of the beach, measured from the last high tide line to the present shoreline are cleaned of all debris, which was collected and returned to the laboratory for analysis. The transects are located at 2, 6.5 and 10 km from the BEACHobs starting point and are cleaned simultaneously with the debris counts. A surveyor's wheel is used to mark out the transects and the beach scraped of all material down to the sand. Forty-one categories of debris were regularly found in these collections (Table 2.3).

Table 2.3: Debris and Litter Categories Used for Garbage "Collections" (1987 - 1988)

A.	The Vegetable Kingdom		
#	Code	Item Weighed	Brief Explanation
16	MANG	Mangrove Seed	Germinating Seeds
17	ALGA	Algae	Green, Brown, Red
18	GRAS	Seagrass	Mostly Green Blades
20	SARG	Sargassum	"New" and "Old"
21	HYAC	Water Hyacinth	All Stages Decomposition
25	BEAN	Sea Bean	Seeds of Tropical Plants
22	WVEG	Woody Vegetation	Stems, Twigs, Roots
19	VEGI	Other Vegetation	(e.g. Morning Glory)

B.	The Animal Kingdom		
#	Code	Item Weighed	Brief Explanation
24	VELA	Velella	"By-the-wind-sailors"
26	PMOW	Portuguese Man-o-war	Physalia physalia
27	CABG	Caggagehead Jellyfish	Stomolophus
28	MLSK	Mollusks	Whole and Fragments
30	DIOP	Diopatra	Polychaetes
31	SDOL	Sand Dollar	Whole and Fragments
32	LEPT	Leptogorgia	Sea Whips (Gorgonians)
33	PENS	Sea Pens	"Pipe Cleaners"
34	STAR	Starfish	Mostly Brittle-stars
35	ANEM	Anemones	-
40	CRAB	Crabs	Generally Fragments
29	INVT	Other Marine Inverts	Many Not Identifiable
36	INSC	Insects	-
39	FISH	Fish	-
37	FETH	Feathers	-

C.	Man-Made Items		
#	Code	Item Weighed	Brief Explanation
1	PLAS	Plastic	Plastic Bags, Pieces
3	STYR	Styrofoam	Pieces
5	TARB	Tar	Tarballs
6	CIGS	Cigarette	Cigarette Butts
7	PBOT	Plastic Bottle	Miscellaneous
8	GLAS	Glass	Pieces
9	CLTH	Cloth	Clothing, Fragments
10	BULB	Light bulb	Including Flourescent
11	PAPR	Paper	Cartons, Pieces
12	CUPS	Cup	Styrofoam, Paper
13	MILK	Milk Jug	1-Gallon, Plastic
14	EGG	Egg	Shell Fragments
15	ROPE	Rope	Polypropylene
23	VEGS	Vegetables	Onions, etc.
2	WOOD	Wood	Dunnage, Pieces Lumber
4	ALUM	Aluminum	Foil
38	ROCK	Rocks	Some Natural
41	MISC	Miscellaneous	Unidentifiable "Stuff"

2.4 Monthly Container Study

San Jose Island is inaccessible except by boat or airplane. The beach is not cleaned of debris and hence litter accumulates there until removed by tides or storms, or buried by drifting sand. All containers on a 250-m transect (marked by surveyor's wheel just north of the North Jetty of the Aransas Pass) along San Jose Island (Figure 1.1) are collected and brought back to the lab for examination. All containers, plastic, glass, metal, and cardboard are collected from the shoreline to the dune line. The material is examined for type, place of origin, color and volume in an attempt to see what percentage of marine litter comes from what countries and what identifiable source (merchant-marine, commercial fishing, etc.).

3. RESULTS

The diagrams presented in this section show histograms of either counts or weights per kilometer of beach (depending on type of survey) plotted as a function of time. Each section is organized by groups representing probable sources of the debris as outlined in Table 3.1. In the left panel, histograms for each individual survey are shown; in the right panel, all pre-MARPOL survey means (April 1987 through December 1989) are compared with post-MARPOL (Jan 1990 - Jul 1992) means. Each page contains several panels grouped by similarity of source or types of items observed. The grouping is based on that outlined in Table 2.1. Sampling frequency is shown at the base of the bottom-most panel on each page. A linear regression line is plotted to scale, but shifted to the mid-point of each vertical axis (because the line would otherwise be "lost" in the data bars). This is due to the extreme noise in the data, a feature of marine debris beaching frequency which makes interpretation of trends difficult. Basic statistics are listed between the left and right-hand panels. Table 3.1 gives an explanation of the data.

Table 3.1: Explanation of Statistical Data for Section 3 Figures

Tot	Total quantity or weight of material were it all to have collected and stayed in the same kilometer of beachfront
nT%	Percentage of times the item was present on the beach
Max	Highest count or weight per kilometer on any single survey
Mean1	Mean of all observations (n)
Mean2	Mean, not including those observations when this item was missing
SD	Standard deviation of linear regression of all observations against time

Note that vertical axes of the panels are annotated in scientific notation to accommodate the wide range of values encountered while the statistical values are given in decimal notation. Because of the huge range of values encountered, these graphs are not plotted using the same scale so attention must be paid to the scale annotation in order to compare magnitudes.

The right-hand panels show the simple means of all pre- and post-MARPOL observations. Note the contrast between the "slope" of the left-hand panel regression lines and the height difference of the histograms on the right. This is due to the difference in scale used on the two panels. The long-term means are usually one order of magnitude less than the scales needed to depict the full range of items counted or weighed on each survey, hence the slopes appear greater on the right. In both cases scaling is chosen to maximize the visibility of the smaller counts or weights yet maintain a readable scale. The Y-ordinate is selected based on the closest value of the maximum count or weight that is less than the following: 0.2, 0.25, 0.4, 0.5, 0.6, 0.75, 0.8, and 1.0 x 10^y, where y is some power of 10. A program was written for this project to display the data in this fashion.

3.1 Debris and Litter by Quantity Counted

The weekly counts are actually done at eight-day intervals to avoid conflicting with our bi-daily BEACHobs. This also permits sampling to be done on every day of the week rather than on the same day each week. A typical sequence of observations and their relationship to day-of-the-week is illustrated below (Figure 3.1). Every seventh and eighth week, observations are made on Saturday and Sunday when the litter on the beach might be increased by the larger number of people using the beach on those days. Although this might appear to obscure the marine source of beach litter, it afforded the opportunity to observe the addition of beachgoer debris. Many volunteer beach cleanups and debris assessments must be done on weekends when sources of litter other than marine-borne may be present.

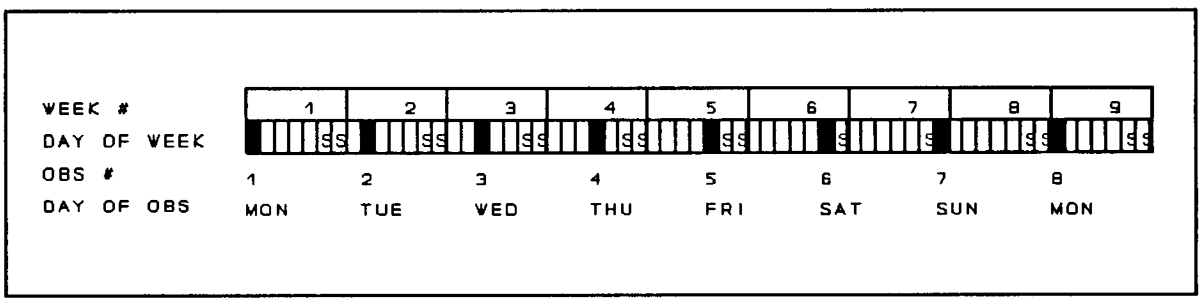


Figure 3.1. Counting Schedule vs Day of Week.

3.1.1 Human Activity

Although human activity is increasing on the South Texas gulf beaches, at the same time the nature of that activity is changing in a way which may affect the beachgoer litter left on the beach. In the late 1970's and up until the mid-1980's, several condominiums were built on the dunes fronting the Mustang Island gulf beach. Prior to that time, the only access to the 11.8-km stretch of beach was by automobile. The condominiums provided access to the beach at many points along the stretch while many people driving automobiles were reluctant to drive far on the sand and the main concentrations of people and beachgoer litter were at the

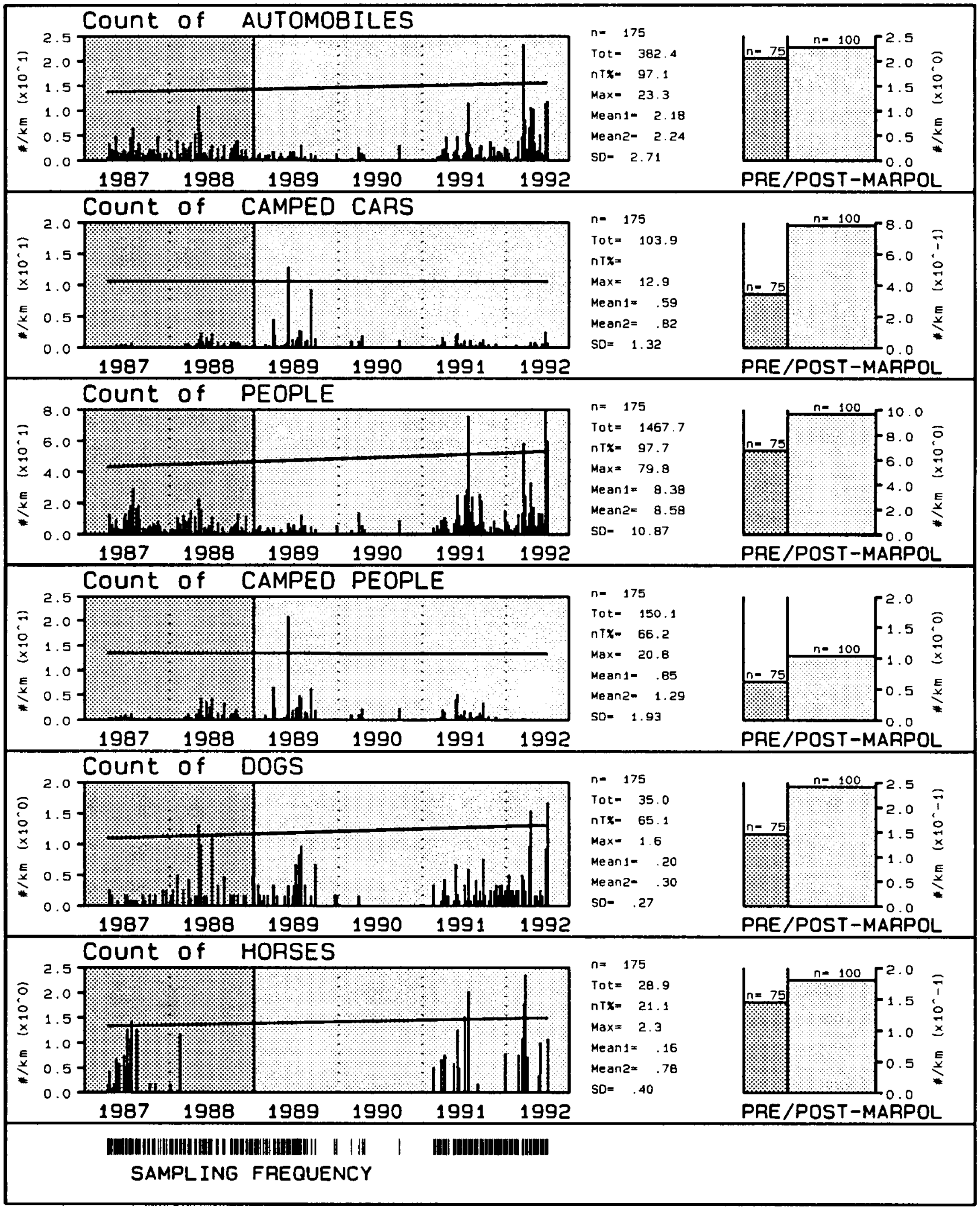


Figure 3.2. People-related Activities: Counts of Automobiles, Camped Cars, Camped People, Dogs, and Horses.

two Access Roads. On the other hand, it took several years for the condominiums to become popular with visitors, but ultimately, while both people and automobile traffic have steadily increased, the ratio of people-to-cars has increased at a higher rate (i.e., there are fewer people visiting the beach by car than are coming there via the condominiums).

People visiting by walking to the beach across the dunes from the condos are also less likely to bring as much litter-producing material with them as are those in automobiles. It is quite common to find evidence of litter left by people visiting by car the morning after their visit. It has been quite popular for people to camp on the beach, driving their cars or recreational vehicles to a spot near the dunes and staying for one, two, or occasionally more nights. This activity, which can also be litter-producing, seems to have declined in the past few years. Figure 3.2 shows some of the people-related activities noted during the weekly counts. Note the increase in people, decreases in automobile traffic and beach-camping and increase in horse traffic from a riding stable located just to the south of the study area. An even more dramatic picture of the increase in human activity on the beach is shown in Figure 3.3 taken from the investigator's 15-year study of Mustang Island gulf beach.

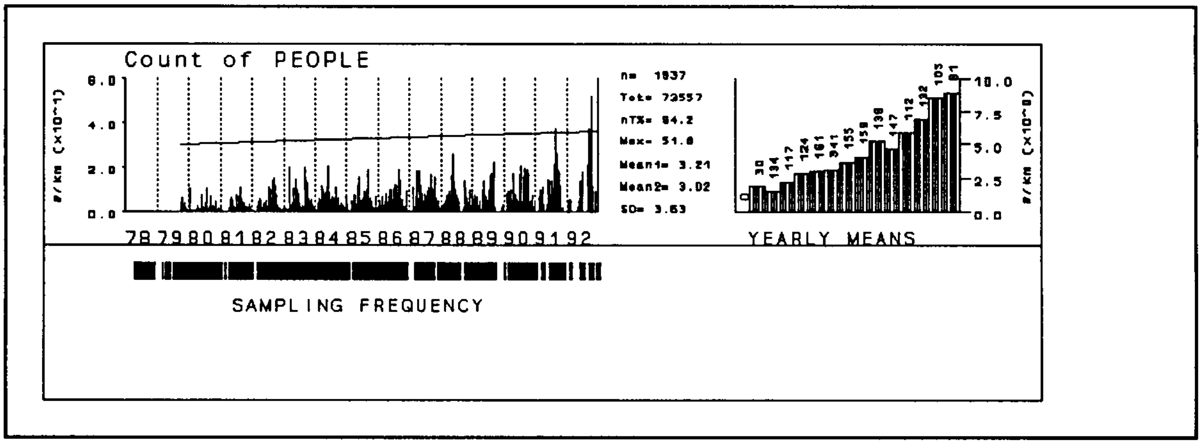


Figure 3.3. People-related Activities: Counts of People Observed on Beach Survey Area, 1979-1992.

3.1.2 Natural Debris

A casual observer of man-made litter on the beach would see that the anthropomorphic material is frequently mixed in with natural debris, most often with the pelagic weed *Sargassum natans*. A closer inspection shows that along with the weed there are many other vegetable and animal species present among the natural debris. Common among these are seagrasses, water hyacinth, mangrove seeds, driftwood, various gelatinous organisms (medusae and Portuguese Man-o-war), bundles of gorgonians, and mollusc shells. Tarballs are also frequent among the debris at the shoreline. The observer might not know when these various items come ashore but would get the general impression that spring and summer time are when most of the debris is beached. As a former casual observer of these beachings, I attempted in these studies to quantify both the natural and man-made debris to see if indeed there was a correlation between the beaching of the two, and to observe the seasonal and long-term patterns to both kinds of material.

Some natural debris items selected for this count include driftwood, coconuts, medusae, and the large mollusc *Atrina* (pen shell). However, the most numerous natural debris items, especially *Sargassum*, are not countable in this fashion. Almost certainly, concentrations of all types of floating debris are mixed in with the *Sargassum* weed which collects in windrows and large patches offshore in the Gulf and often washes ashore together on the high tide. This uncountable natural and not-so-natural debris is evaluated by weight during the weekly collections study (section 3.3).

For the following, refer to Figure 3.4. Portuguese Man-o-war (*Physalia physalia*, referred to as PMOW from here on) come ashore mainly in the spring and summer, and occasionally in winter. The cabbagehead jellyfish (*Stomolophus*) is a winter and spring item. Pen shells appear in fall and early winter, coconuts in summer, and driftwood year-round. Apart from their "countability", which is not easy at the best of times, the reasons for looking at these items rests in their probable origins. PMOW is associated with the tropical waters of the Caribbean and central Gulf of Mexico, cabbageheads are often abundant in the bays, pen shells are inhabitants of the shallow nearshore region where sunken and waterlogged litter items are often concentrated, and coconuts are borne into the sea by the rivers of Mexico or from tropical beaches there and in Central America. Driftwood presents a special problem. Some is the result of tree-cutting both in Mexico and the U.S., some is from erosion of river banks during flooding and storms, some is in the form of dunnage, and some is from the degradation of piers, docks, and abandoned or wrecked vessels. Hence it may be both natural and "man-made". In Figure 3.4 pre- and post-MARPOL information is given for contrast with the man-made debris, although (with the exception of dunnage which shows little trend) MARPOL has no bearing on beachings of these items.

3.1.3 Fishing Industry

Figure 3.5 groups commonly found items that almost certainly come from the offshore fishing industry. Off the Texas coast this is restricted to shrimping and a much smaller longline fishing industry. Some items could overlap with other sources such as the seismic exploration and recreational fishing industry. The **floats** in the top panel are usually from fish nets or lines. The trend has been decreasing and the type of floats has changed in the past few years. Fewer of the metal and plastic deep-sea floats come ashore now; they are quite a rarity where they were once commonplace. This may reflect less effort by foreign fleets in the Gulf of Mexico as EEZ regulations came into law. The cold chemical **light sticks** are used by longliners to attract fish to the baits and are purchased in bulk. They are used only once. These have declined in the post-MARPOL era. **Dead fish** are often recognizable (by species composition) as being the by-catch from the shrimping industry. Some are left by local wade fishermen who consider them "trash". An increase in beached fish has been observed. Monofilament **fishing line** has its origin mostly from recreational fishing. It has decreased. Fifty-pound woven plastic **produce sacks** are apparently used by brine boats in the shrimping fleet to bag shrimp for processing at sea; post-MARPOL, they have increased on the survey

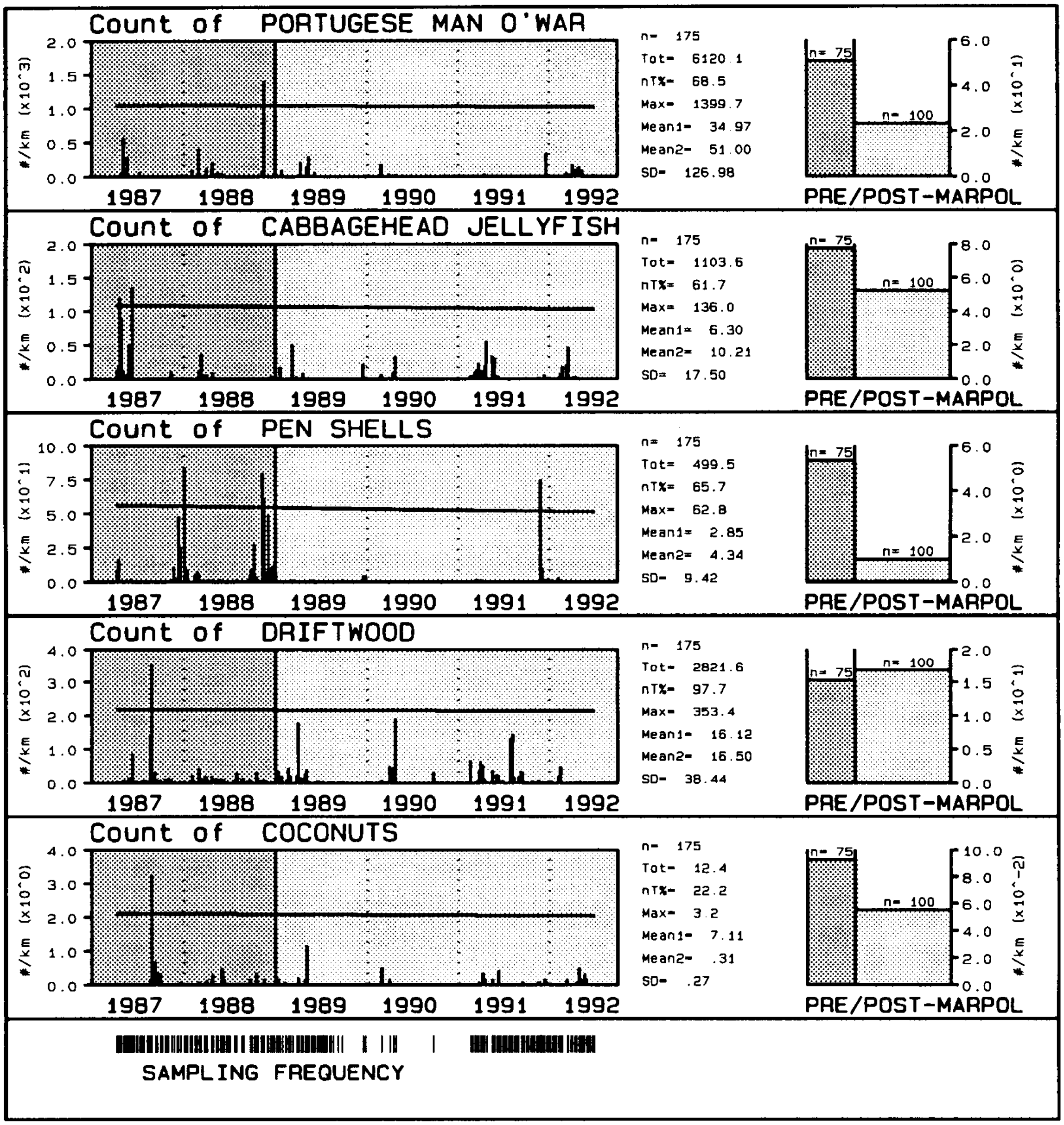


Figure 3.4. Natural Debris: Counts of Portuguese Man-o-war, Cabbageheads, Pens Shells, Driftwood, and Coconuts.

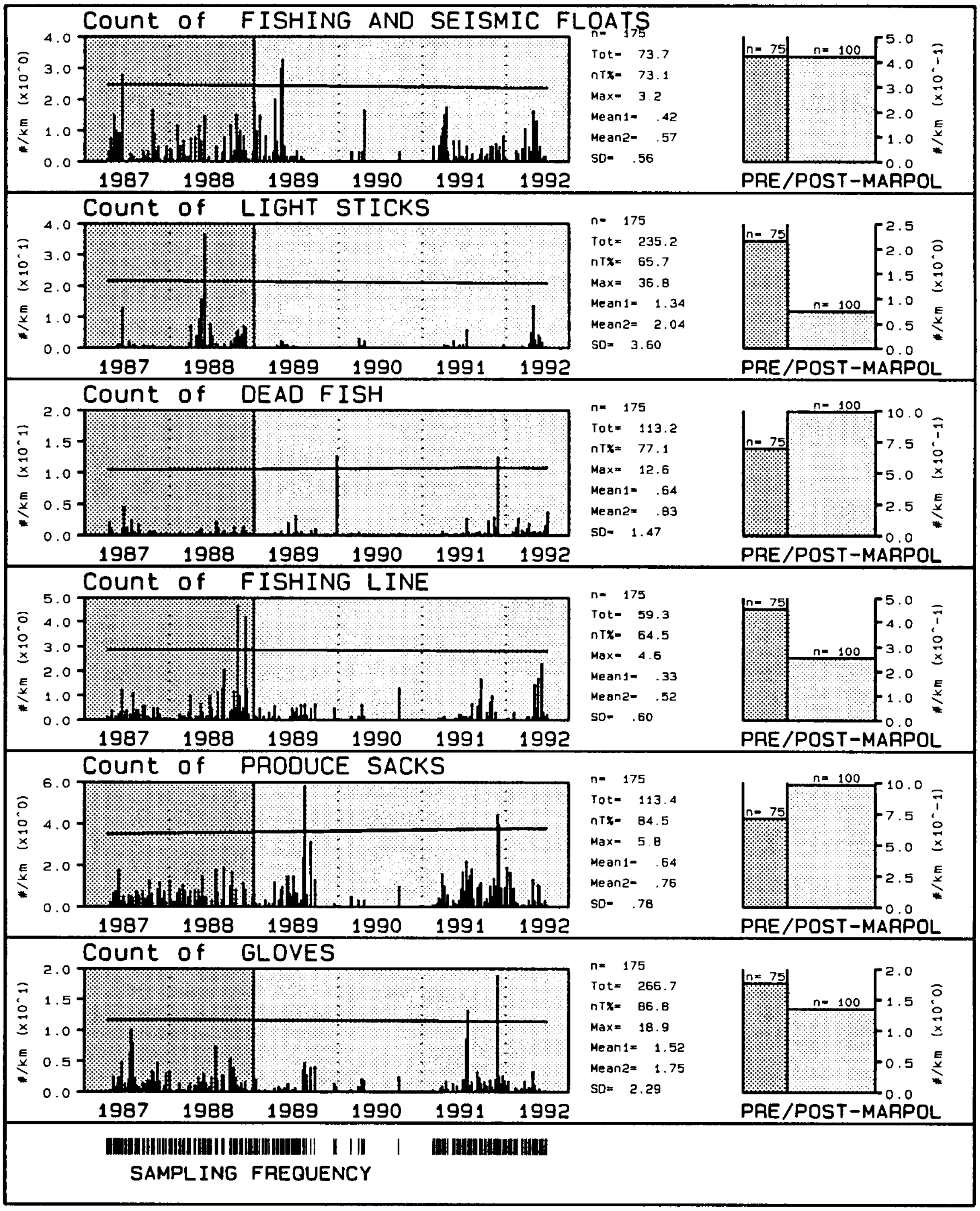


Figure 3.5. Fishing Industry Litter: Counts of Floats, Light Sticks, Dead Fish, Fishing Line, Sacks, Gloves, Green Bottles, and Shrimpboats.

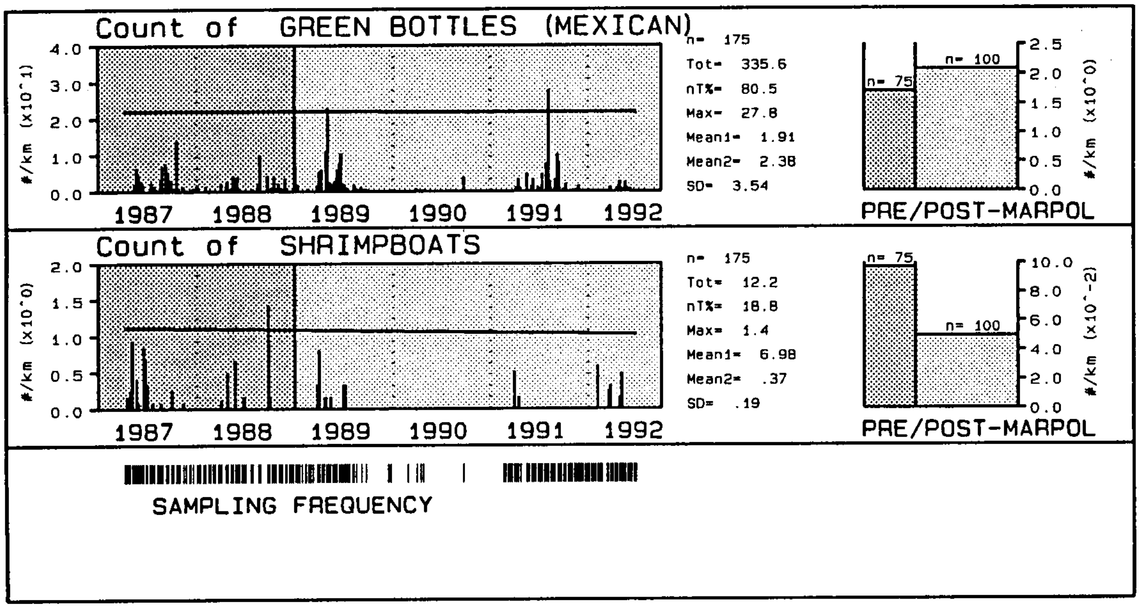


Figure 3.5. (cont.) Fishing Industry Litter: Floats, Light Sticks, Dead Fish, Fishing Line, Sacks, Green Bottles and Shrimpboats.

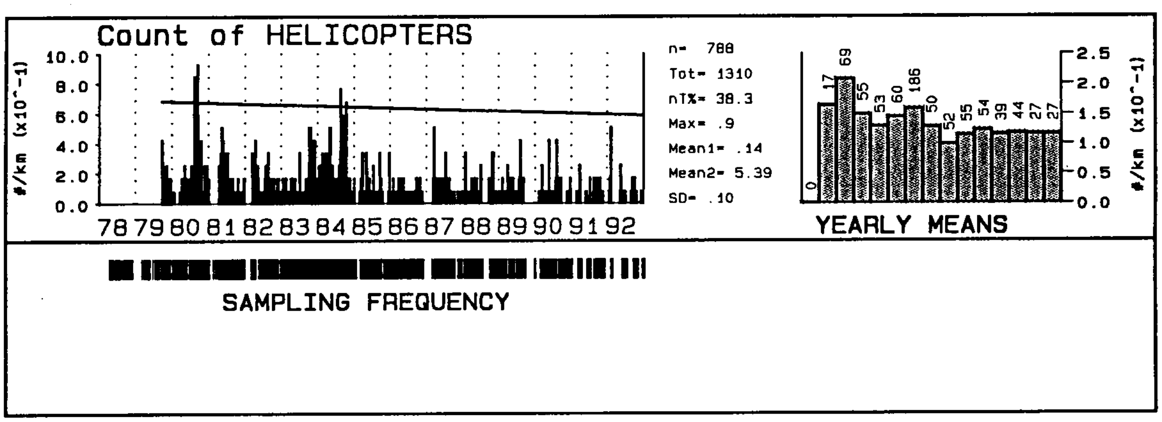


Figure 3.6. Offshore Oil Industry-related Items: Helicopters Observed on Beach Survey Area, 1979-1992.

beach. Rubber or plastic **gloves** are used on shrimp boats; they have remained at the same level before and after MARPOL. **Green bottles** from Mexico are ribbed plastic bottles, usually 750 ml or 1 liter size, of two or three popular brands ("Clarasol", "Cloralex") of household bleach. They appear on the beaches in a disproportionate number compared to other Mexican domestic items. It is believed that they are used by the shrimping fleet, perhaps to prevent a bacterial shrimp infection known as black or brown spot (Cipriani, *et al.* 1980). Counted weekly, they show a post-MARPOL decline (but see section 3.1.2). Finally, the shrimpboats themselves are counted. These are the boats visible from the beach as the surveys are done. They are seldom numerous in this area, and their numbers have declined, particularly the so-called "Bay Boats" shrimping close to shore for white shrimp.

3.1.4 Offshore Oil Industry

Several platforms and other structures dot the marine landscape visible from the survey beach. Exploration and drilling activities are commonplace sights from the beach. Jack-up rigs, work boats, "mud" boats and helicopters are indicators of the service industry's activities. There has been a decline in the offshore oil industry in recent years. As evidence for this decline, Figure 3.6 shows the trend since 1979 in the number of helicopters counted from the survey beach. Figure 3.7 includes four items typical of this industry. Five-gallon (usually) **plastic pails** that contain chemicals and oils are used offshore in drilling and maintenance of platforms and rigs; there has been a notable reduction in these items since MARPOL. Protective **hardhats** are commonly washed ashore, often bearing decals of company names identifying their source. A slight increase in hardhats has been recorded post-MARPOL. One item which has essentially disappeared from the beaches are the plastic **write-protect rings** used by seismic research vessels to protect data recorded on magnetic tape from being over-written. There has also been a drop in the number of pieces of heavy-duty **plastic sheeting** on the beach since MARPOL. This material is used to cover palletloads of supplies and equipment; its source is primarily offshore oil activity, but could also have other industrial sources.

3.1.5 Maritime Commerce

The merchant marine industry contributes to the marine debris on the study beach, but the distinction between items typical of this industry and those of the offshore oil and fishing industries is often blurred. All use certain types of supplies and containers that ultimately become beach litter, but certain items may be typical of that particular industry. Perhaps unique to freighters and tankers plying the Gulf is the use of one-liter cardboard cartons of long-life milk (milk which has been irradiated or heat-treated and requires no refrigeration). Also most of the foreign (with the exception of Mexico) litter on the beach has its source on merchant marine vessels which are often foreign-flagged and take on supplies in European, Middle Eastern, South American or Asian ports. In Figure 3.8, post-MARPOL reductions were recorded in **cardboard cartons**, **lightbulbs** and **fluorescent tubes**, while **ropes and hawsers** show a slight increase.

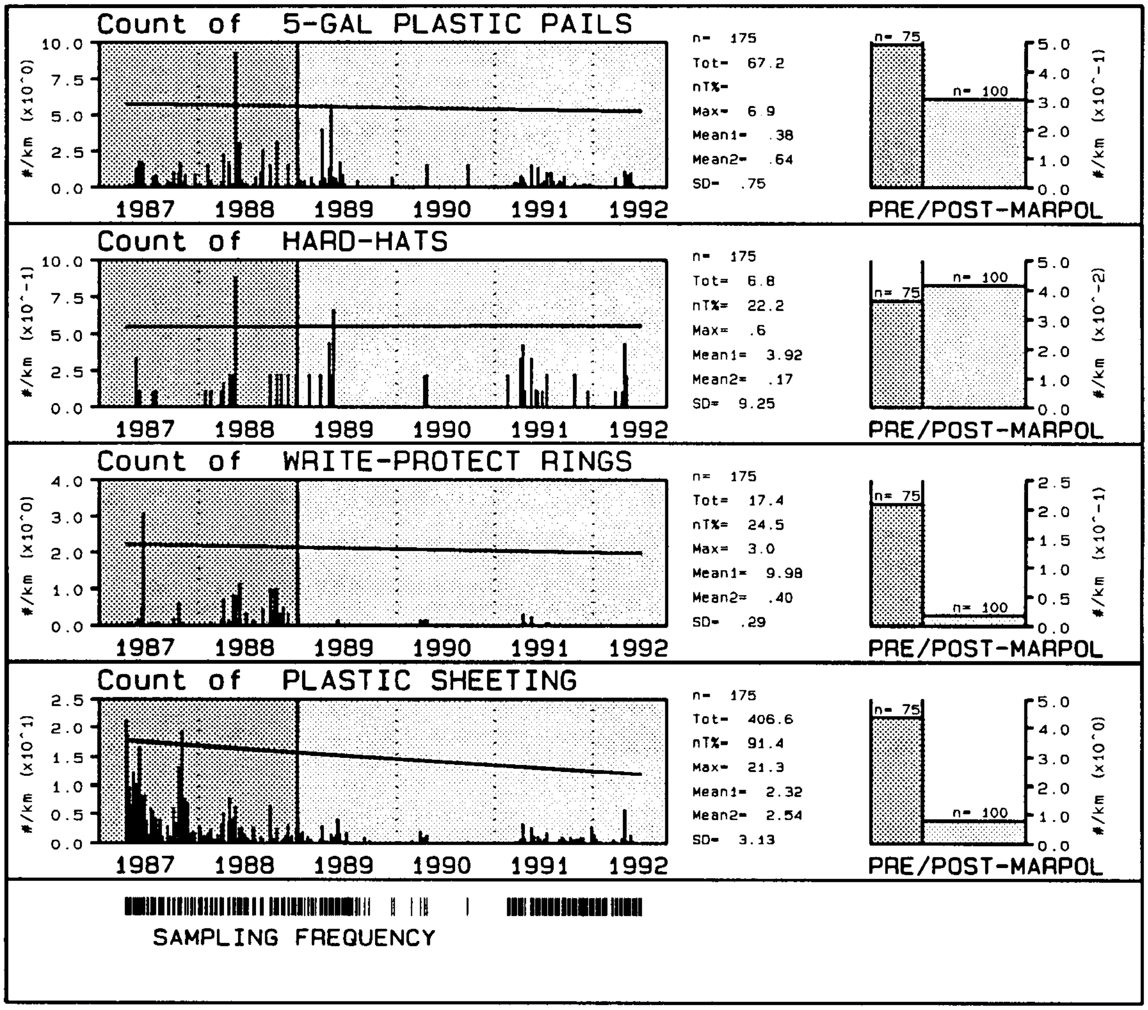


Figure 3.7. Offshore Oil Industry-related Items: Counts of Pails, Hard Hats, Write-protect Rings, and Plastic Sheeting.

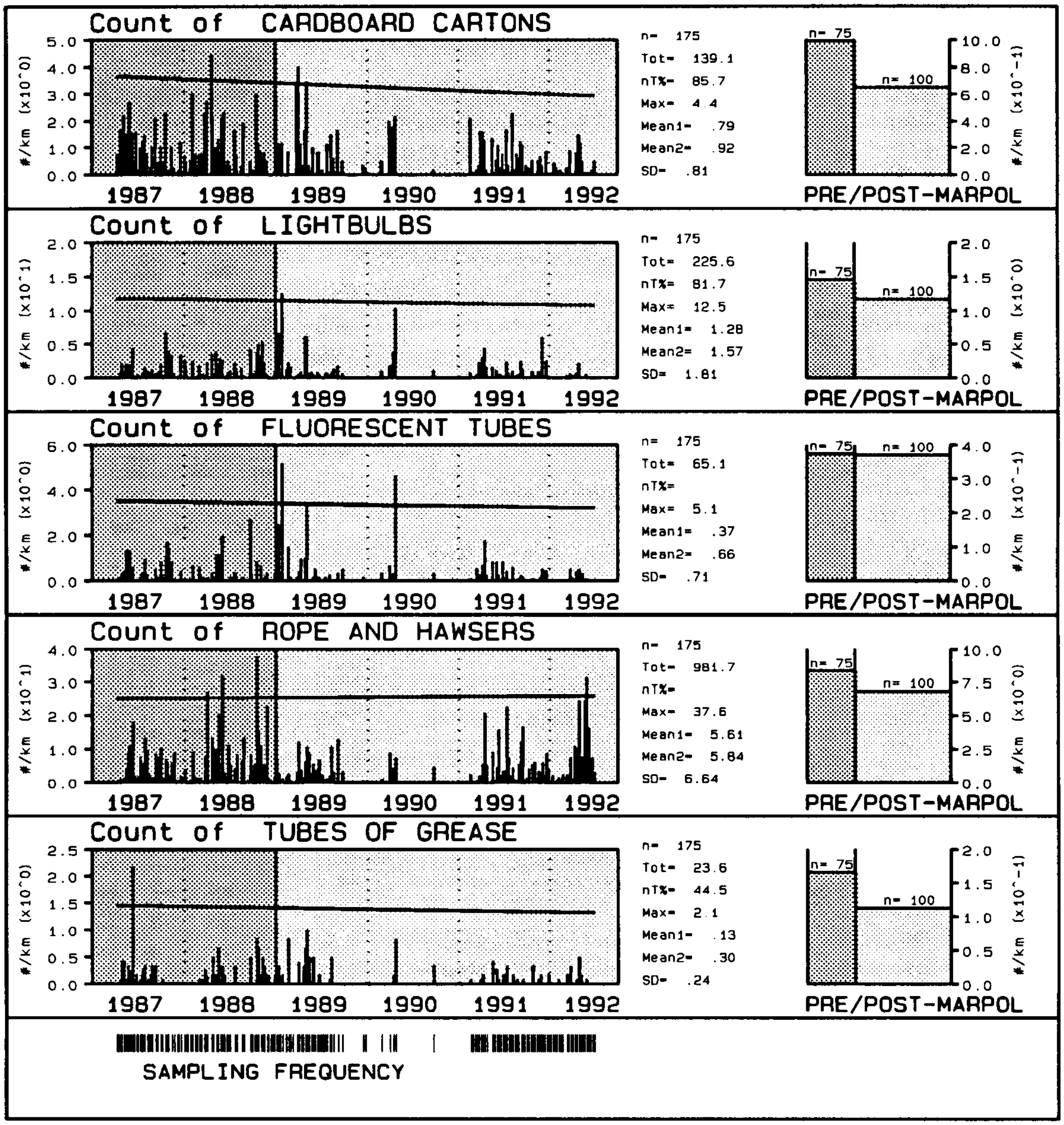


Figure 3.8. Merchant Marine Litter: Counts of Cardboard Cartons, Lightbulbs, Flourescent Tubes, Ropes, and Hawsers.

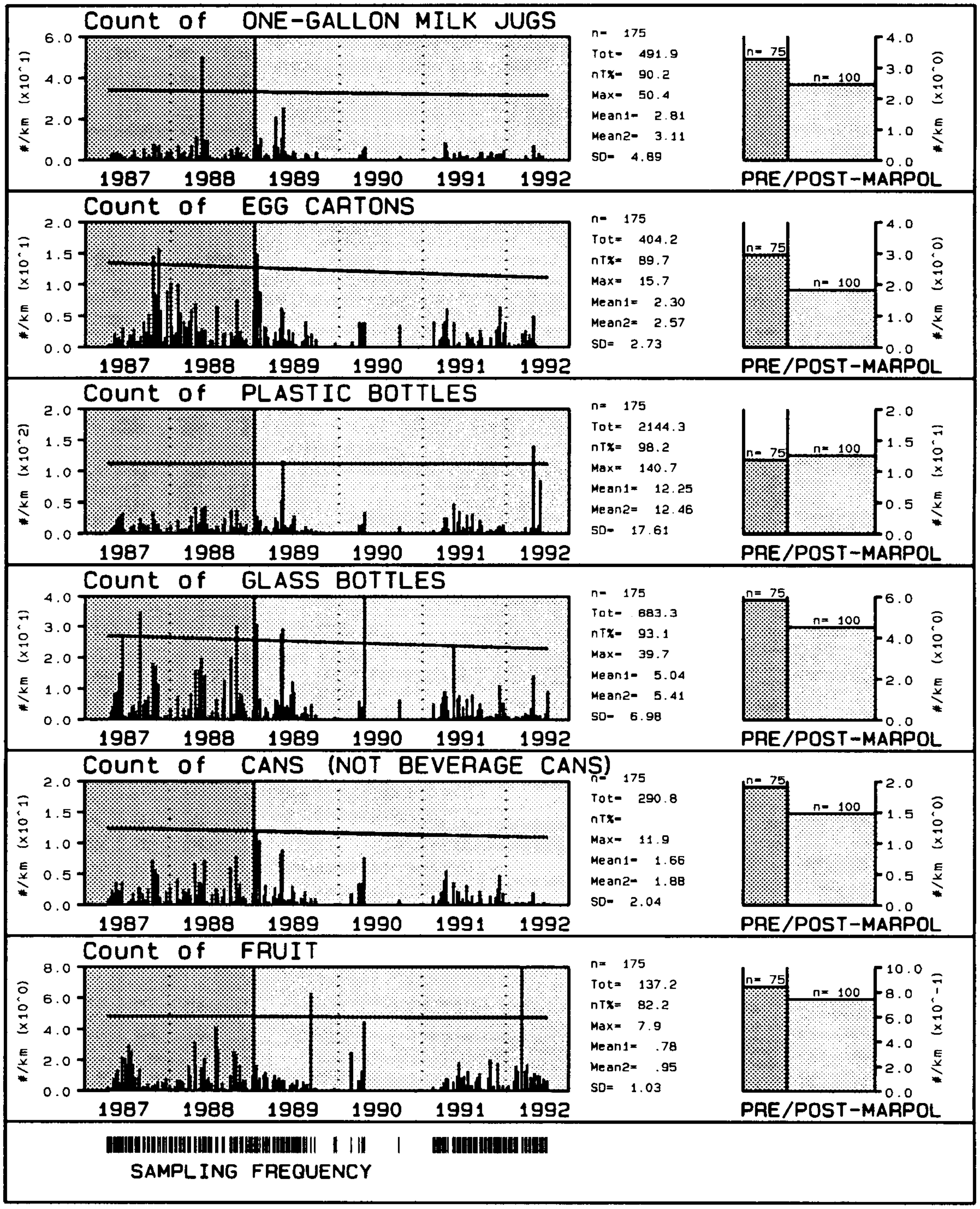


Figure 3.9. Galley Waste: Counts of Milk Jugs, Egg Cartons, Plastic Bottles, Glass Bottles, Tin Cans, and Fruit.

3.1.6 Galley Waste

The litter generated in ship, boat, and platform kitchens is commonly found on the survey beach. It is comprised of usually empty bottles and food cans, cleaning and toiletry products, coffee grounds, vegetable peelings, and food-packaging materials. Some items such as the numerous one-gallon domestic milk/water jugs almost certainly come from the shrimping fleet. Others could come from any of the other sources where food is prepared and people are accommodated offshore. In Figure 3.9, post-MARPOL declines have occurred in all of the items in the diagram (**milk jugs, egg cartons, plastic and glass bottles, cans and fruit**).

3.1.7 Miscellaneous Items

The source of the **miscellaneous items** shown in Figure 3.10 cannot be easily identified; yet they form the most numerous types of litter on the beach, especially the plastics. The only item to have increased since MARPOL is the **miscellaneous plastic pieces**, a catch-all category consisting of broken hard-plastic peices. This does not include styrofoam or plastic-bag peices or lids, but plastic cutlery, combs, toothbrushes, fragments of bottles and lids are included. **Styrofoam pieces** have become noticeably less numerous on the beach, as have **plastic bags**. However, a typical problem with evaluating many of these items is that there is a great spike in the plastic bag "crop" in the fall of 1988, and the standard deviation is three times the mean.

3.1.8 Beachgoer Litter

The final group of materials has been designated **beachgoer litter**, meaning that its probable source is from visitors to the beach who leave their litter discarded there. Again, it is not possible to say with certainty that all of this material is left by beachgoers. Some could come from recreational boats fishing offshore, or could wash out of the bays. The most typical of this type of litter is aluminum **beverage cans**; in Texas these are mostly beer cans, but also include soft drink cans. Numbers of these cans have remained nearly constant, but the associated **plastic six-pack ring** which presents an entanglement danger to marine life has declined. **Paper products**, **plastic toys**, and **balloons** have increased while **drink cups**, **clothing**, and **shoes** have declined (Figure 3.11).

3.1.9 Indicator Items

After the first year of GARBGobs was completed in April 1987, it seemed desirable to try and assess certain key items of debris more frequently. Figure 3.12 shows the trends in the five items over 501 observations (334 for beverage cans which were not included in the counts until mid-1989). The result is a post-MARPOL decline in all of these categories with the exception of the Mexican green bottles. Because these items were counted on both GARBGobs and the BEACHobs count of five, we combined the two data sets to produce Figure 3.13. Now with an almost continuous set of data (n=667) from 1987 to 1992, the trends remain very similar; reductions in all items with a very slight increase in the **green bottles**. There is

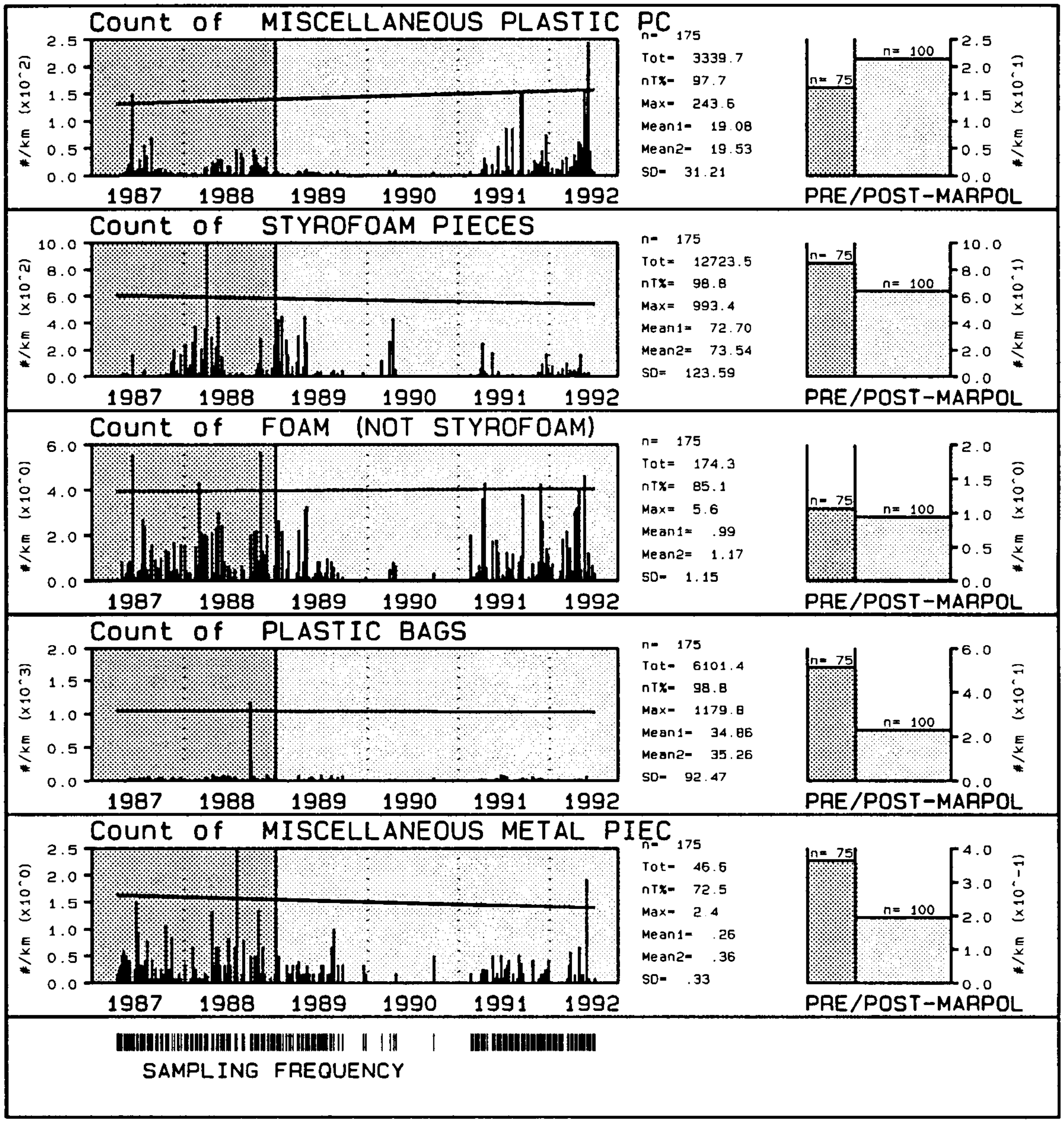


Figure 3.10. Miscellaneous Litter: Counts of Plastic Pieces, Styrofoam, Foam, Plastic Bags, and Metal Pieces.

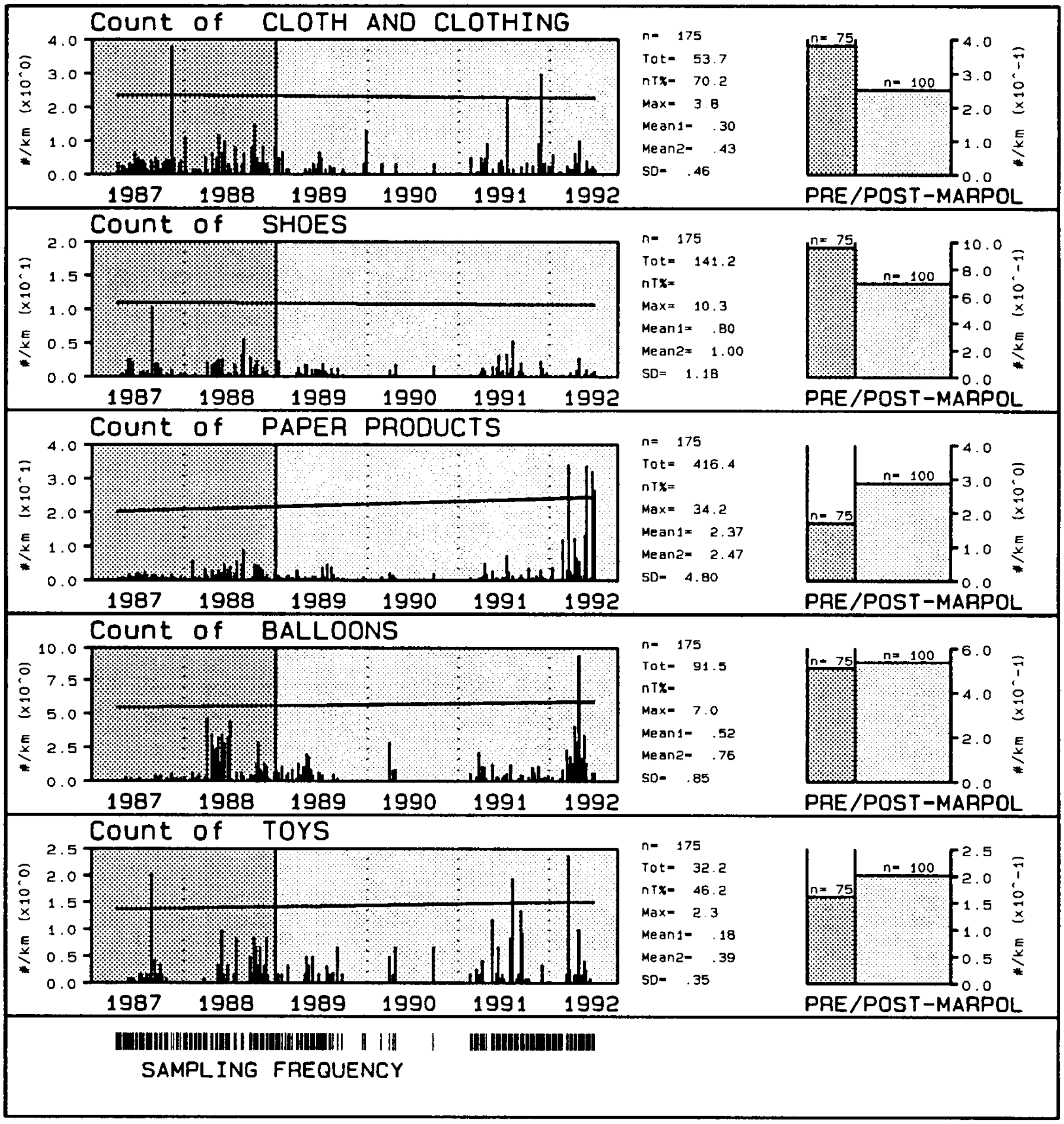


Figure 3.11. Beachgoer Litter: Counts of Clothing, Shoes, Paper, Balloons, Toys, Beverage Cans, 6-Pack Rings, Cups, and Lids.

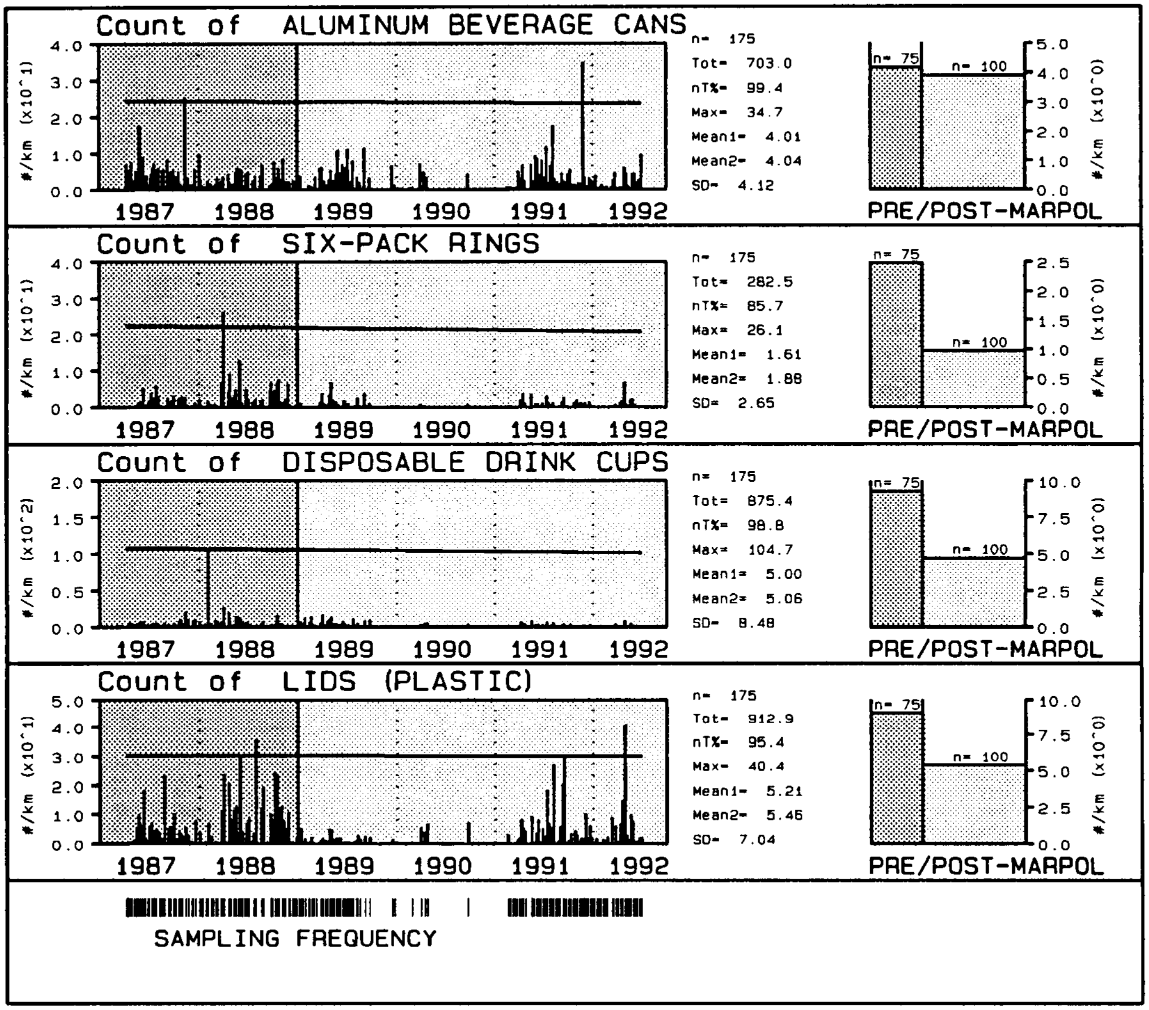


Figure 3.11. (cont.) Beachgoer Litter: Counts of Clothing, Shoes, Paper, Balloons, Toys, Beverage Cans, 6-Pack Rings, Cups, and Lids.

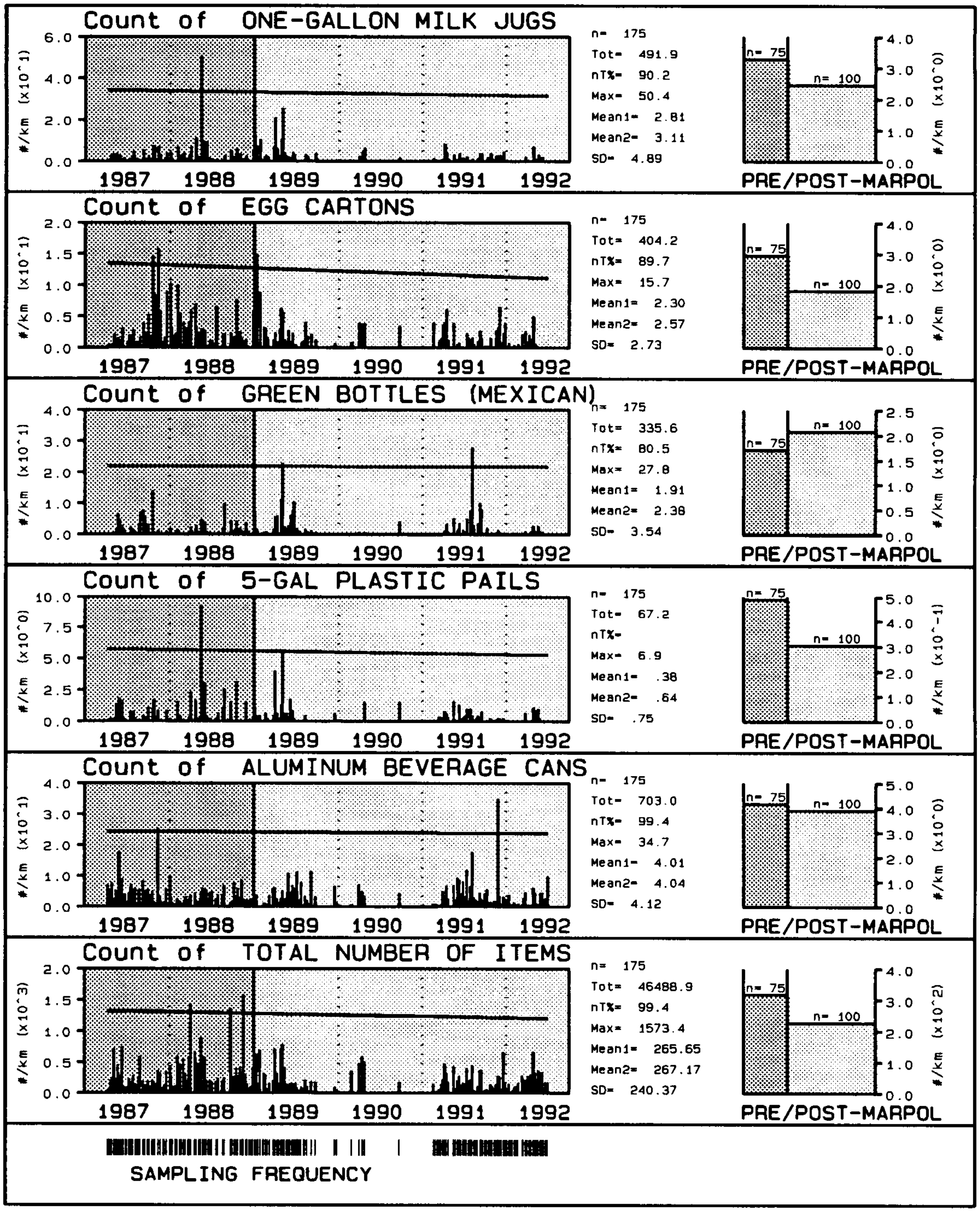


Figure 3.12. Indicator Items: Bi-Daily Counts of Milk Jugs, Egg Cartons, Green Bottles, Chemical Drums, and Beverage Cans - Total Items.

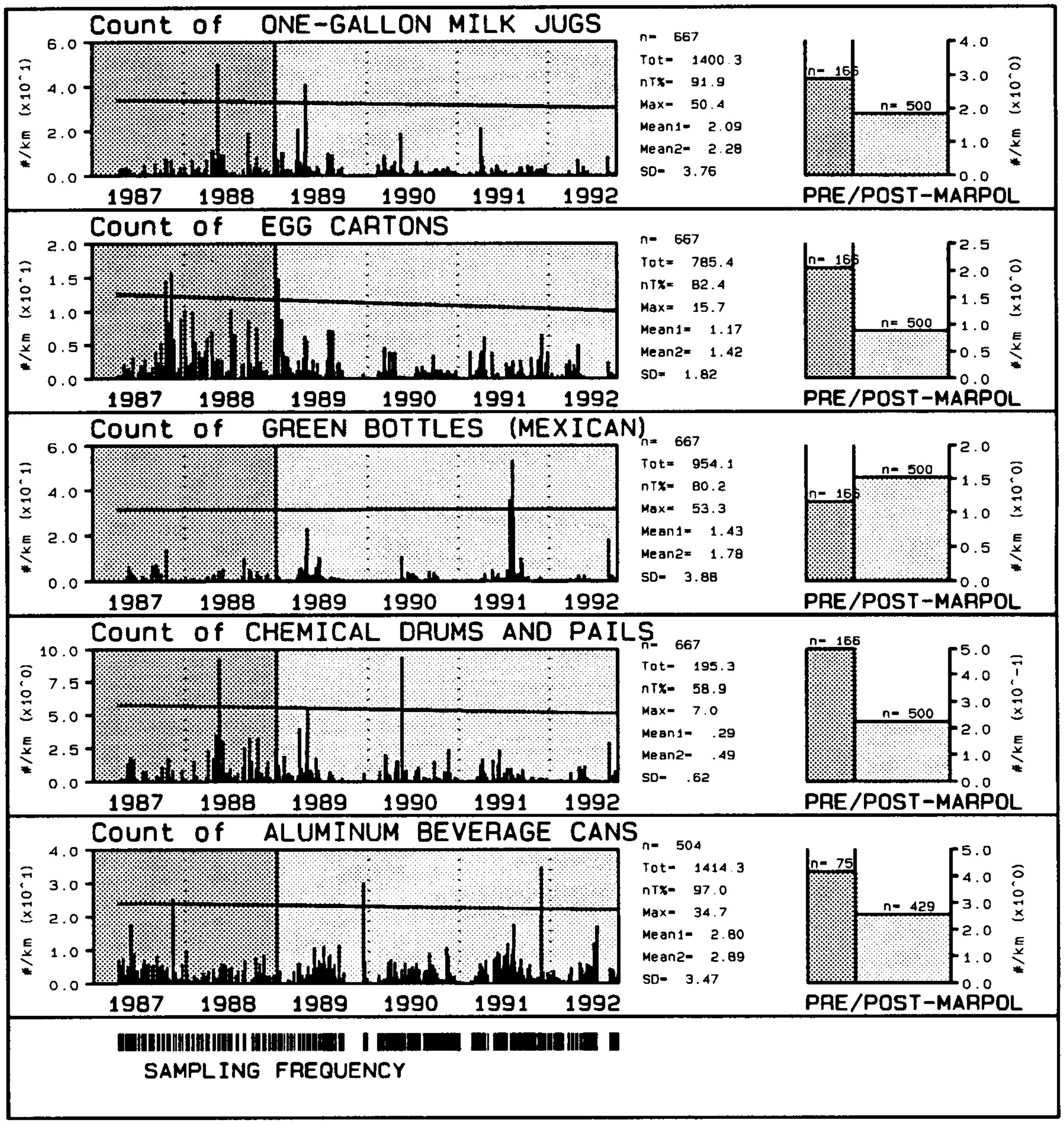


Figure 3.13. Indicator Items: Combined Weekly and Bi-Daily Counts of Milk Jugs, Egg Cartons, Green Bottles, Chemical Drums, and Beverage Cans - All Observations.

consistency of occurrence of the indicator items on the beach (**beverage cans**, 97%, **milk jugs**, 92%, **egg cartons**, 82%, **green bottles**, 80%, and 5-gallon **pails** of chemicals, 59%). Reductions of 50% in numbers per kilometer of beach have been realized in the post-MARPOL era. Note, however, a similar reduction in beverage cans, the source of which is mostly from areas not covered by MARPOL.

3.2 Evaluation of Count Results; Errors

Several factors govern the effectiveness of these counts in determining trends in the quantity of debris on the beach. When attempting to isolate those items discarded at sea and affected by MARPOL, the factors multiply. This study, although started long before MARPOL went into effect, targeted items to count that were *indicators of origin* rather than *type of item* (where one might use a multitude of item categories). Natural items were added as another indicator of origin; certain algae and animals typical of either gulf or bay waters appear in quantity on the beach along with associated litter.

The start point of the 11.8-km survey beach is 10 km south of the Aransas Pass entrance to Corpus Christi Bay and 100 km north of the Mansfield Channel (Figure 1.1). Debris, both natural and man-made, is not always evenly distributed along the 11.8-km of beach. Frequently, debris thins out in quantity going south (the direction in which the survey progresses). The nature of human usage of the beach is changing. More people now visit the beach, especially from the condominiums which are mostly located south of the survey's kilometer 6. When this beach was chosen as a site suitable for surveying, it was sparsely used because of the relatively long distance between the two access roads (the primary access then being by vehicle). As more people used the beach, the city and county effort to clean it of debris intensified. Table 3.2 briefly summarizes the usage of the beach.

Table 3.2: Summary of Beach Usage and Cleaning

Kilometer	Jurisdiction	Usage
0-0.75	Port Aransas	Free parking*; near access road; beach cleaned regularly by city; beach camping.
0.75-4.75	Nueces County	Parking fee*; one condo; beach cleaned irregularly; beach camping.
4.75-7.0	Nueces County	Concentration of condos; beach cleaned intensively**.
7.0-8.0	Nueces County	No condos; beach cleaned regularly.
8.0-10.5	Nueces County	Several condos; beach cleaned intensively**.
10.5-12.0	Nueces County	No condos; beach cleaned regularly; near access road; beach camping permitted.

*Parking regulations and fees have changed several times.
**Intensive cleaning using beach-rake equipment starting in 1992.

To record the items counted and human usage as a function of distance along the survey beach, the electronic odometer is used to "map" their location. Some problems with the odometer prevented this from being used for all observations. Following the first year (April 1987-May 1988) most surveys were terminated at the 6-km point. Upon resumption of surveys in 1992 for this project, the full distance was covered, except when the debris load was so heavy that it would have taken an inordinately long time to complete. Figure 3.14 shows the frequency of the odometer usage and the total distance covered on all weekly counts. Indicator items counted bi-daily always cover the full 11.8-km length of the survey beach.

3.2.1 Accuracy of Counts

It is difficult to assess the accuracy of the counts. The author has made the great majority of all observations with the exception of several in 1992 which were done by trained assistants. Counts are more prone to be in error when litter items may be obscured by natural debris, particularly *Sargassum*. Items which can be counted with minimum error such as milk jugs, bottles and other containers, and those subject to greater errors such as styrofoam pieces and natural debris, are marked in Table 2.1. Errors are on the side of under-counting rather than over-counting. Re-counting is not avoided during the surveys. More accurate counts are made on days when there is less material to count. In addition, the tendency is to count smaller items on those days of little debris which might get ignored on days when the load is high.

3.2.2 Effect of Beach Cleaning on Counts

While beach cleaning is not the only agent of debris removal from the beach, it is the main factor on the survey beach. Other agents include littoral drift, transport by high tides to the dunes, and burial by sand. Another form of beach cleaning over which there is no control is that done by beachgoers who pick up litter and deposit it in the trash receptacles. This is a common activity of people who spend the winter in the condominiums. While it is a laudable citizen effort, it does not help the garbage counters.

3.2.3 Distribution of Items Along the Survey Beach

Table 3.3 lists the condominiums and other landmarks along the survey beach in distance from the survey's starting point at Gulf Beach Access Road #1. The numbers in the left column refer to numbered locations in the figures to follow (Figures 3.15 through 3.20). In these diagrams, the counts have been averaged into 250-m bins so that the distribution of people, natural debris and various litter along the survey beach could be examined. Densities of each bin are in numbers per kilometer to be consistent with the other data presented in this report. Averaging in each bin was done by year, season, and all years from 1987 to 1992. In this section we present the distribution of several different items averaged over the whole study period only. Appendices C and D include seasonal and annual plots for the same categories. In the diagrams, kilometer marks are shown from left-to-right as a function of distance south of

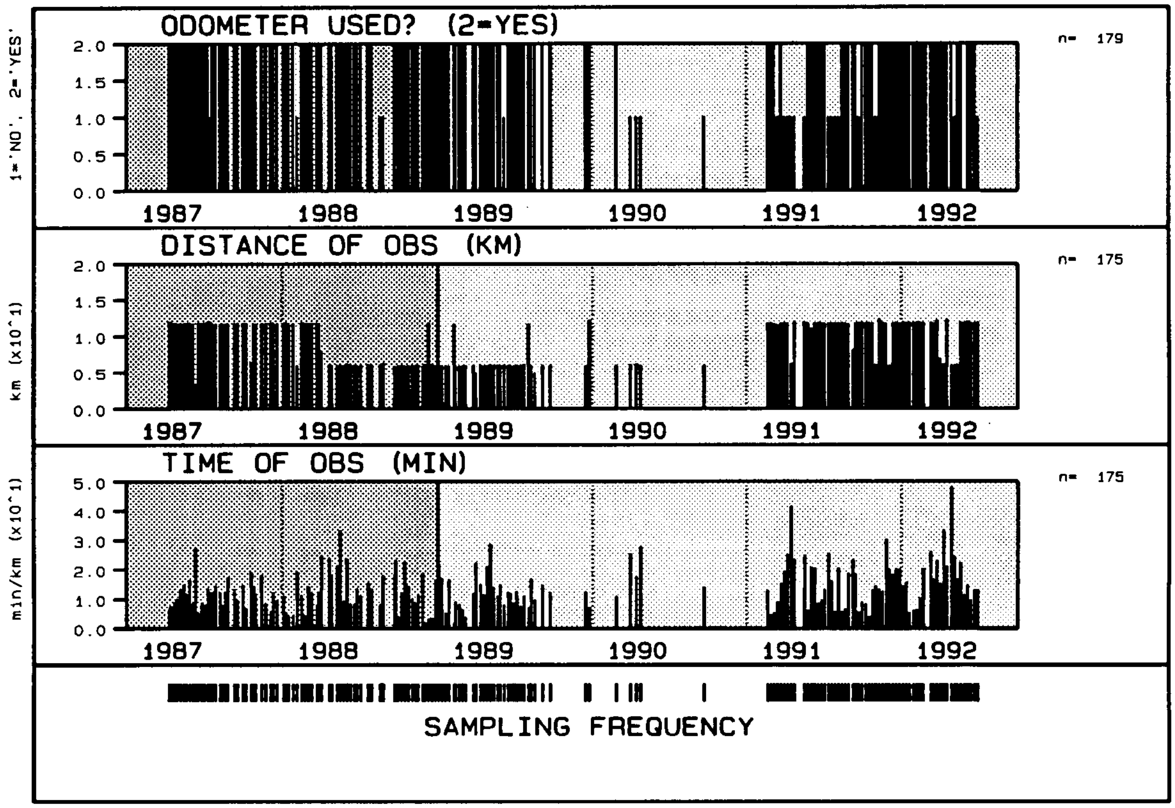


Figure 3.14. Evaluation of Data: Use of Electronic Odometer, Distances and Times of Surveys.

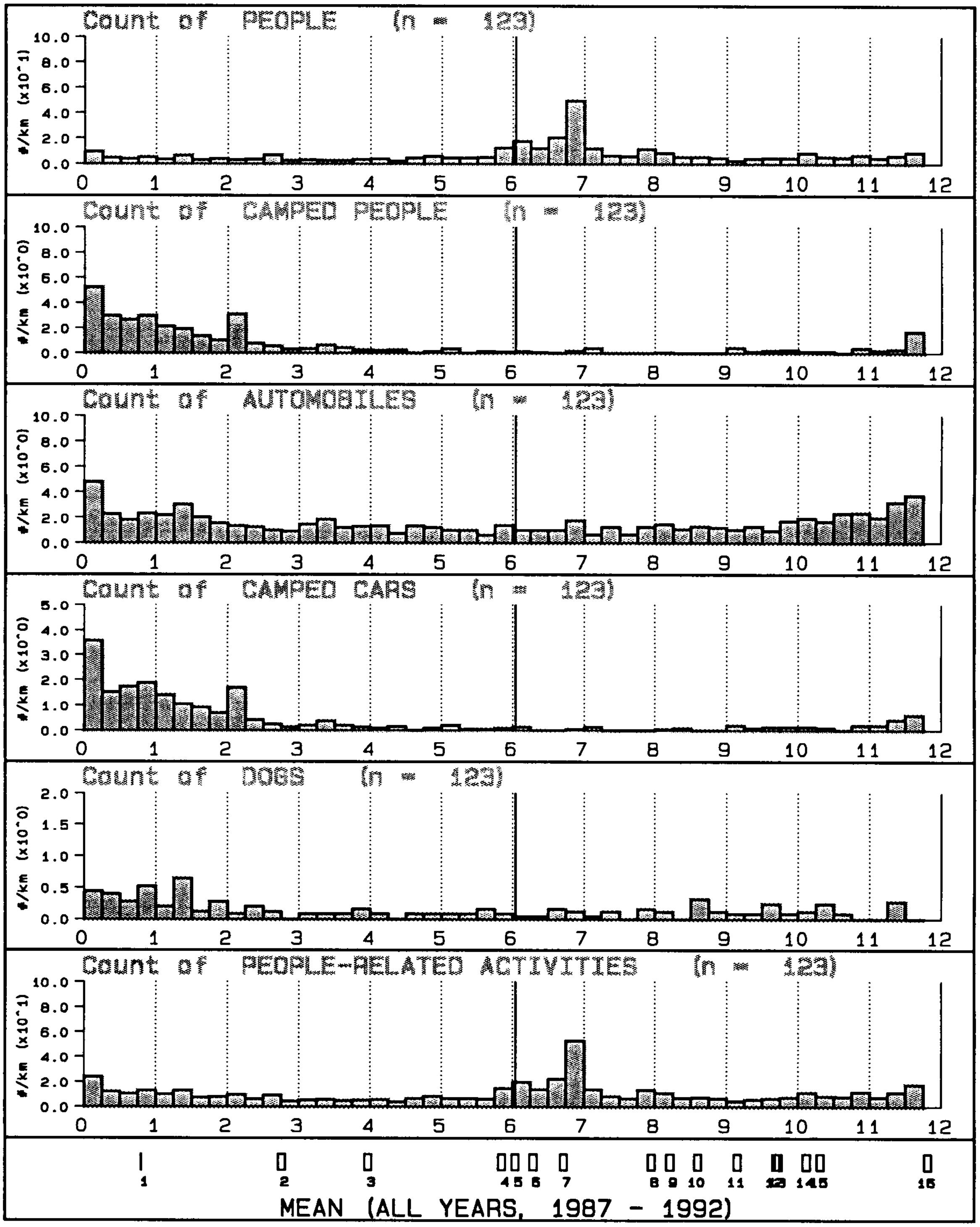


Figure 3.15. Distribution Along the Survey Beach: Count of People, Camped People, Automobiles, Camped Cars, Dogs, and People-related Activities.

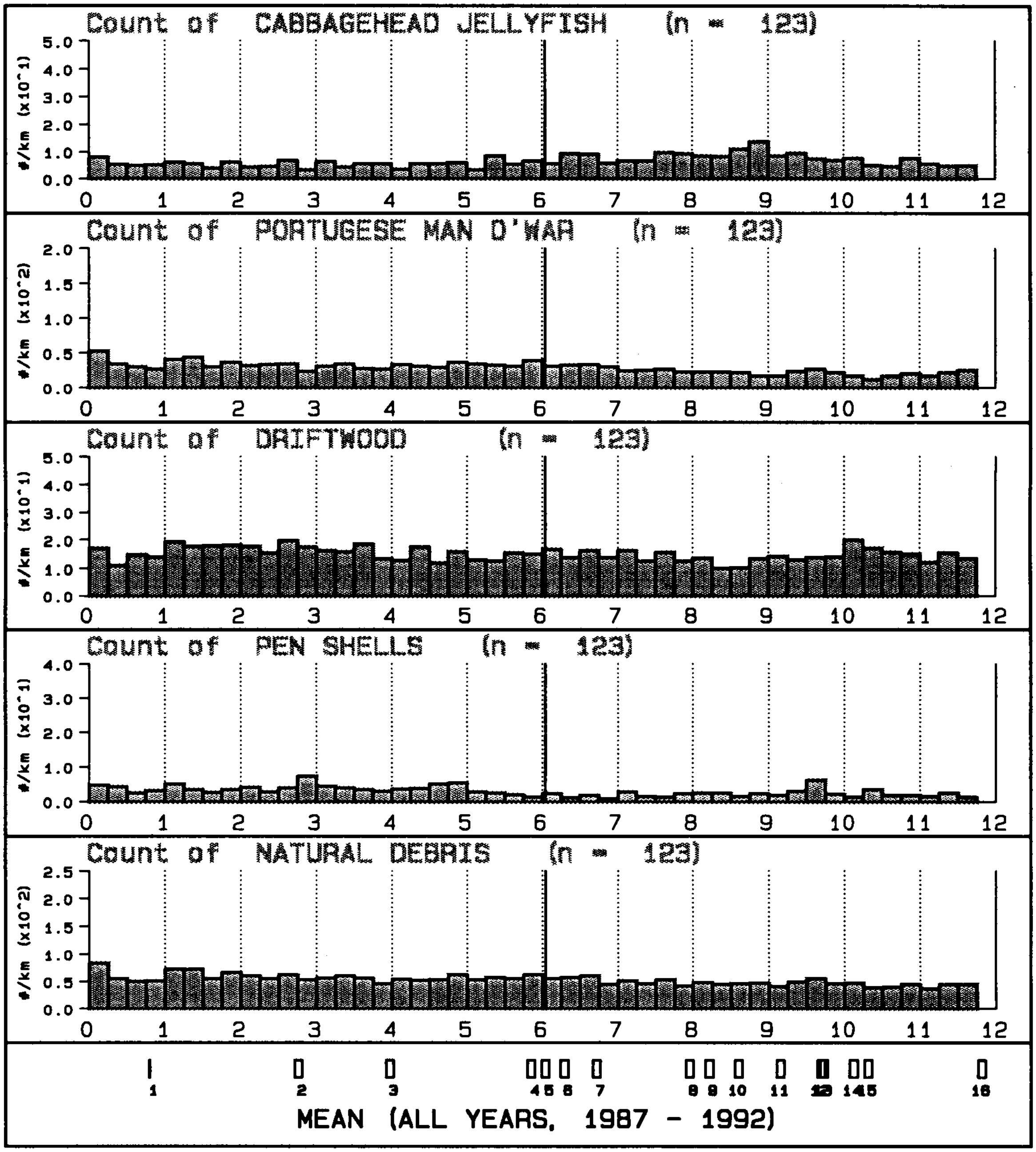


Figure 3.16. Distribution Along the Survey Beach: Count of Cabbagehead Jellyfish, Portuguese Man-o-war, Driftwood, Pen Shells, and Natural Debris.

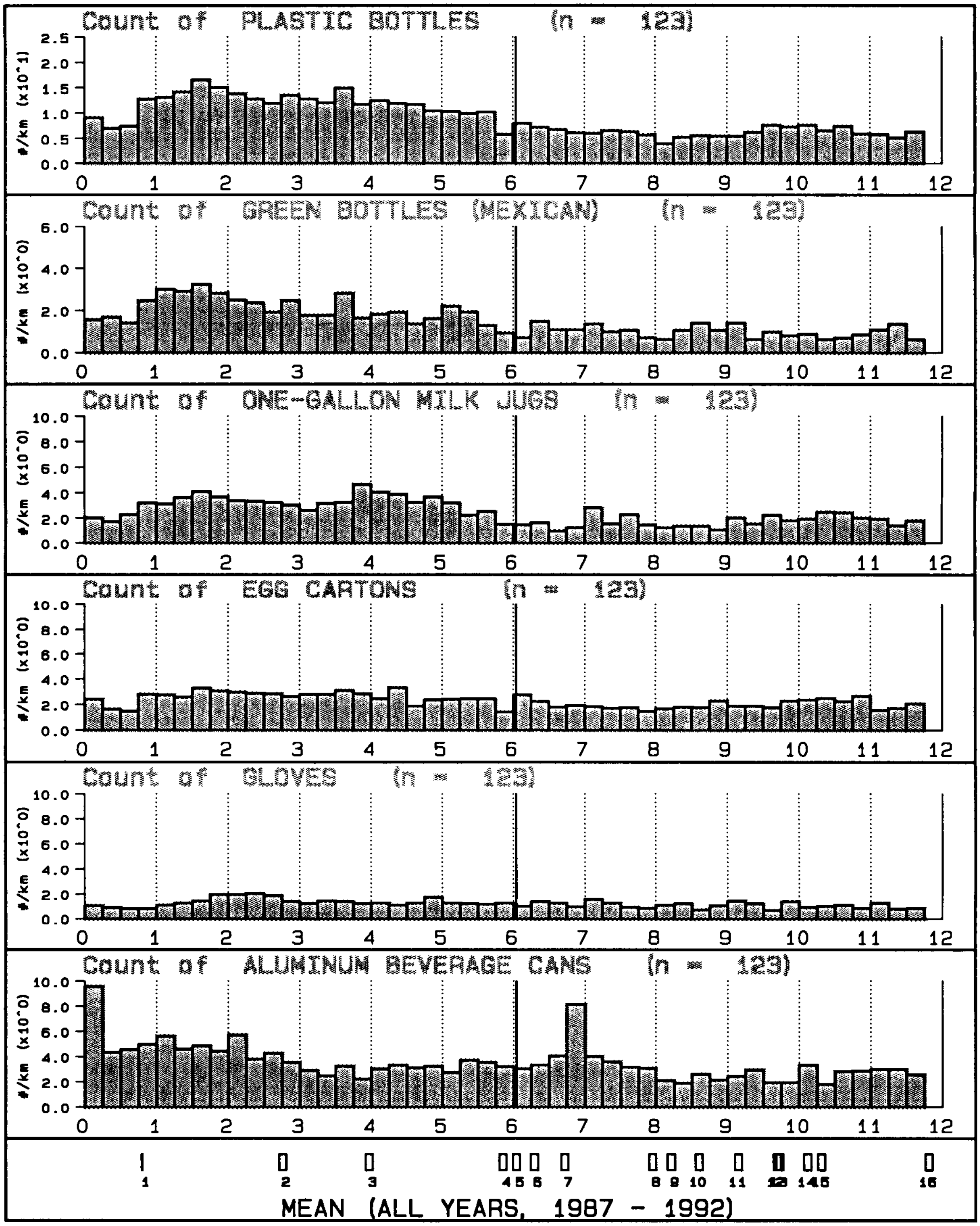


Figure 3.17. Distribution Along the Survey Beach: Count of Plastic Bottles, Green Bottles, One-Gallon Milk Jugs, Egg Cartons, Gloves, and Beverage Cans.

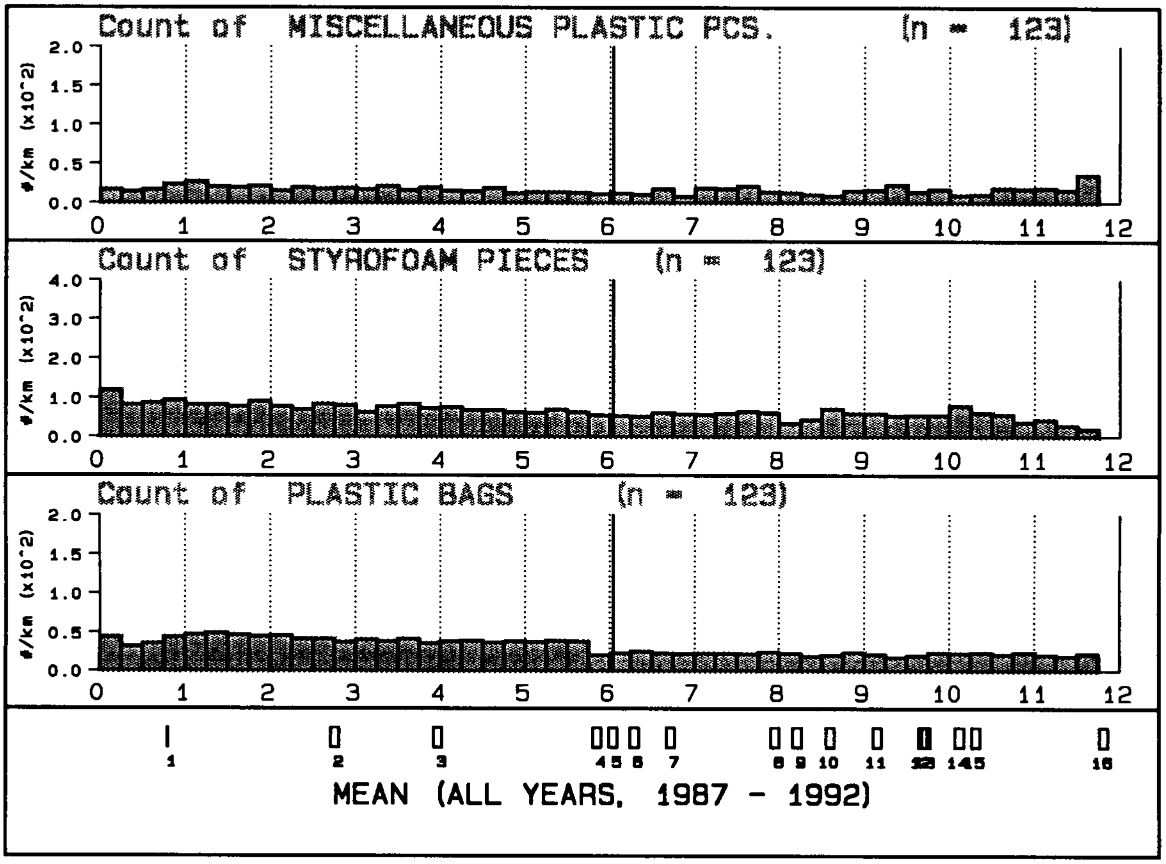


Figure 3.18. Distribution Along the Survey Beach: Count of Miscellaneous Plastic Pieces, Styrofoam Pieces, and Plastic Bags.

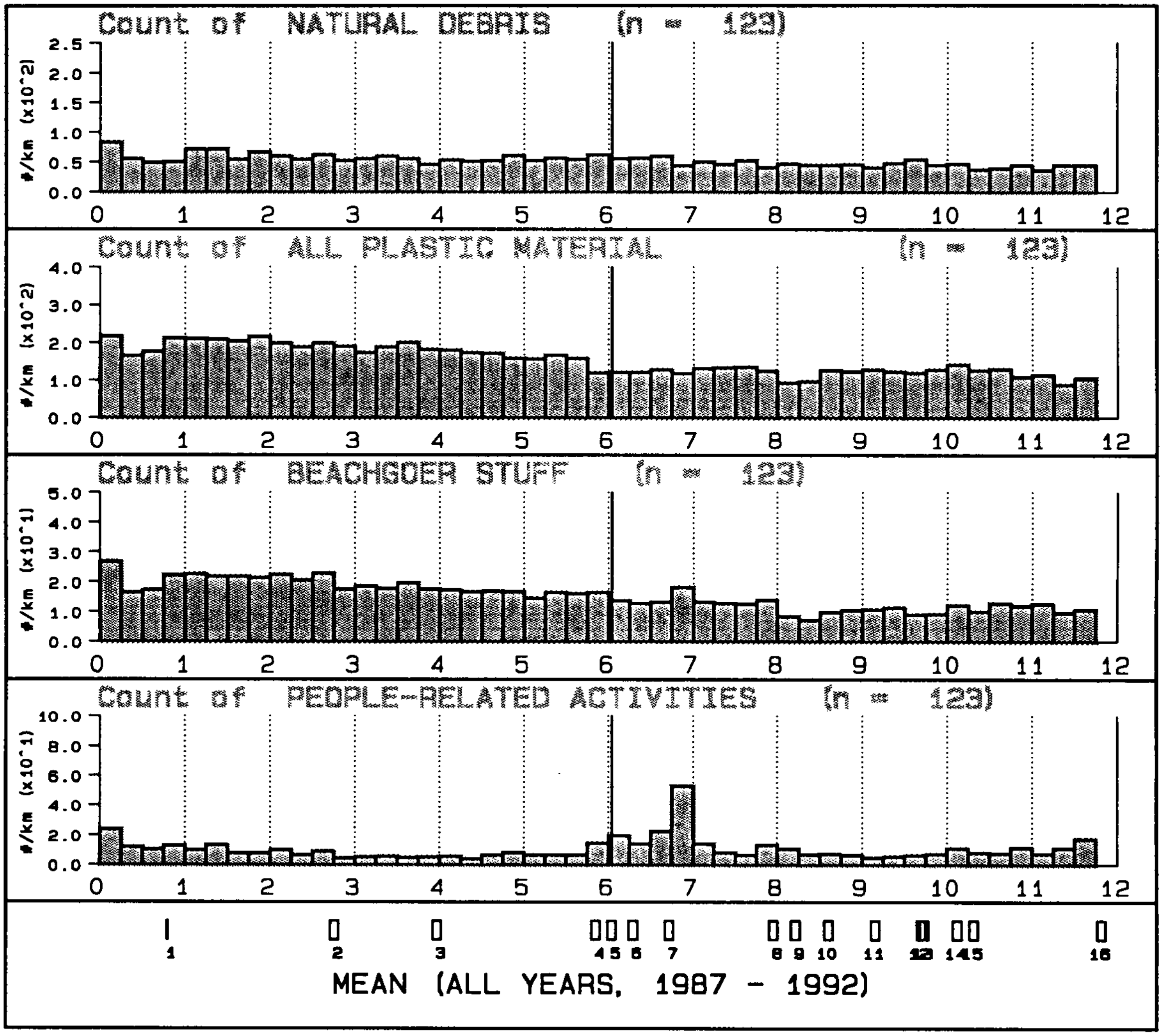


Figure 3.19. Distribution Along the Survey Beach: Count of Natural Debris, Plastic Material, Beachgoer Stuff, and People-related Activities.

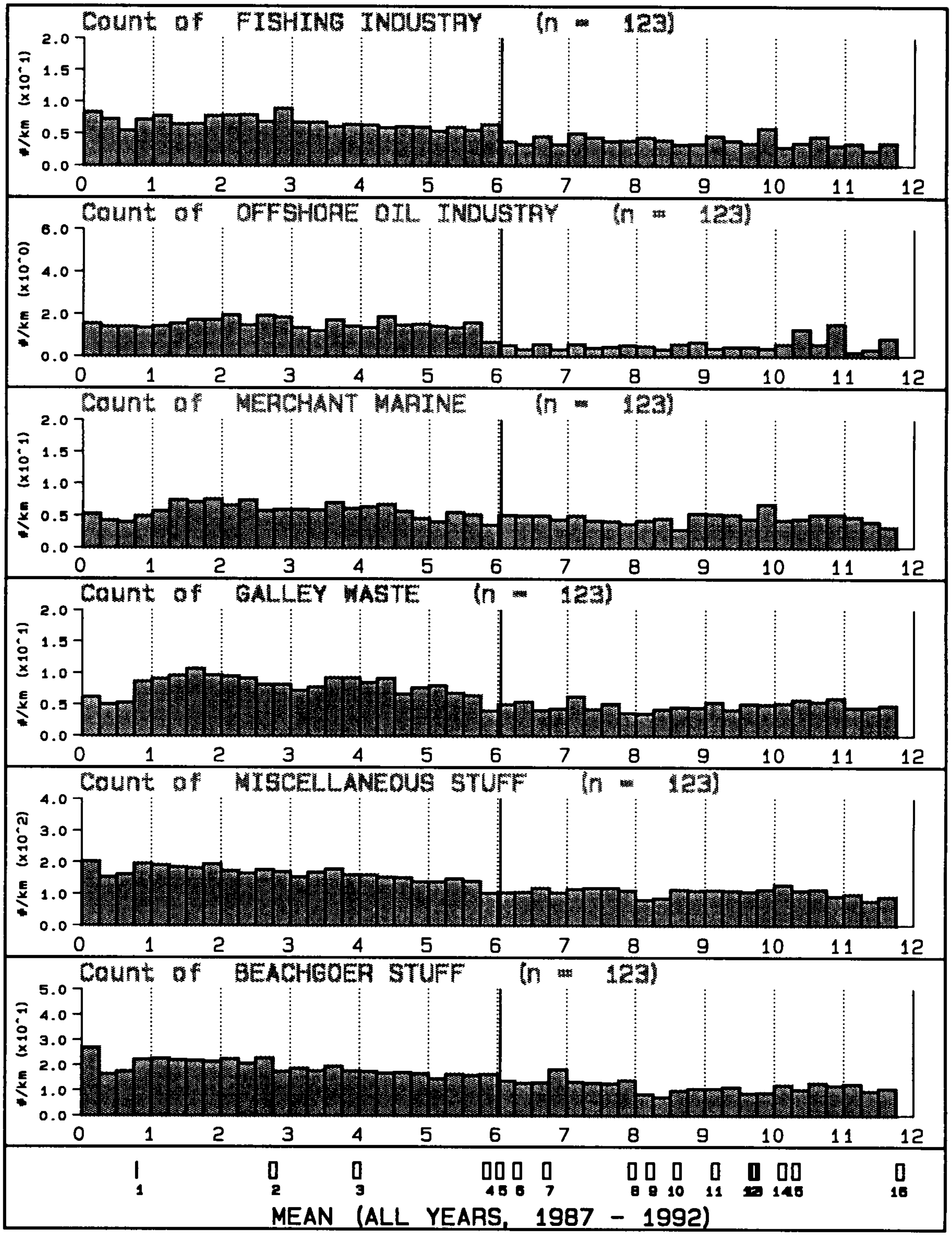


Figure 3.20. Distribution Along the Survey Beach: Counts Indicative of Particular Sources--Fishing Industry, Offshore Oil Industry, Merchant Marine, Galley Waste, Miscellaneous Stuff, and Beachgoer Stuff.

Access Road #1. At the bottom of each group of panels the numbered boxes and vertical lines refer to the location of condominiums and other landmarks listed in Table 3.3. The solid vertical line at km-6 at Gulf Shores Condominium is the dividing line between the actively-cleaned beach to the south and the sporadically-cleaned beach to the north. It is also the terminating point for several GARBGobs, especially in late 1988 and in 1989.

Figure 3.15 shows the usage of the beach by people. It clearly illustrates the dominance of the access roads and the condominiums in attracting people to the beach. Natural debris has no such affinity (Figure 3.16), being nearly evenly distributed along the beach. A selection of litter items (Figure 3.17) does show some trends in their geographic distribution. **Plastic bottles, green bottles,** and **milk bottles** clearly show a reduction in numbers within the more intensely-cleaned City of Port Aransas area next to Access Road #1 and south of kilometer 6 to Access Road #2.

Beverage cans show a distribution mirroring the popular areas of the beach. The three plastic items which are the most numerous items on the beach (**miscellaneous plastic pieces, pieces of styrofoam,** and **plastic bags**) show a more even distribution (Figure 3.18). These smaller pieces of plastic are not as efficiently cleaned by beach crews as are the more obvious items. The larger plastic bags do show a trend in the southern half of the beach. Figure 3.19 compares the combined categories of **natural debris, all plastics,** those items including plastic and other materials typical of **beachgoer** items, and the combined activities of **people** (cars, dogs, etc). The quantity of natural materials shows no trend along the entire beach. Plastics and beachgoer stuff decline in the regularly cleaned half of the beach. People are concentrated around the condos and access roads. It should be noted that the scales chosen for these diagrams are consistent for any one item so that the variations are directly comparable. Those presented in the main body of the text are overall means which are lower than say those in Appendix C for selected time periods during the study. Finally, items indicative of particular sources are compared in Figure 3.20. All of these show a lessening in numbers going from north to south, especially from the condominiums and south. This distribution reflects beach-cleaning in that area. It must also be pointed out that while $n=123$ for these observations they include several observations which stopped at kilometer 6. This also affects the overall mean from that point south.

Table 3.3: Location of Landmarks on the Survey Beach

#	Distance		Description
	Miles	Km	
0	0.0000	0.000	Beach Access Road #1
1	0.4993	0.791	Port Aransas City Limit
2	1.7370	2.754	Casadel Condominiums
3	2.5010	3.966	Residence
4	3.6849	5.844	La Mirage Condominiums
5	3.8047	6.033	Gulf Shores Condominiums
6	3.9628	6.284	Mustang Towers Condominiums
7	4.2347	6.715	Port Royal Condominiums
8	5.0125	7.949	Sea Gull Condominiums
9	5.1752	8.207	Sandpiper Condominiums
10	5.4213	8.597	Lost Colony Townhomes
11	5.7699	9.150	Walkway to Residence
12	6.1076	9.685	First Private House
13	6.1342	9.728	Second Private House
14	6.3778	10.114	Admiral's Row
15	6.5016	10.310	Mayan Princess Condominiums
16	7.4466	11.809	Beach Access Road #2

3.2.4 **Import and Export of Debris on the Study Beach**

Do the counts done at weekly intervals reveal how much material is washing ashore from the gulf? The ideal condition for the study would be to immediately clean the beach following each count so that the next one would assess only material newly washed up in the interval. This cannot be done so we make the assumption that this does happen either by man's action or nature's intervention. During the bi-daily count of five, certain large items are recognizable from count-to-count. On an 8-day observation schedule this is seldom the case. To examine this "import and export" of debris on the beach, Figures 3.21 and 3.22 were constructed. Figure 3.21 shows selected common litter items counted during GARBGobs with import (accumulation) as positive values (# per km) and export (removal) as negative values. In all cases accumulations seldom last for more than two surveys and most times a big influx of material "disappears" by the following survey. Unfortunately, the occasional huge import of materials (see **plastic bags**, for example) reduces the more normal ebb and flow of material to insignificance as illustrated in these diagrams. Nonetheless it would appear that the counts are reasonably representative of new materials coming ashore although it is impossible to put error bars on these data.

A similar picture is revealed on a bi-daily surveying schedule as shown in the import and export of the five indicator items counted (Figure 3.22). In each of these figures the net accumulation is given at the right. In all cases except **green bottles** there is a net accumulation.

3.3 **Debris and Litter by Weight**

Weekly collections of debris at three sites on the survey beach (Figure 3.23) are used to evaluate the quantity and frequency of items of litter too small to be counted and natural debris which cannot be counted. Figures 3.24 through 3.27 show the results of the weekly collections of litter and debris by weight per km. The diagrams follow the same form as those described in the introduction to section 3. There are 41 categories of items commonly found during the collections. These are tabulated in Table 2.3. The detailed breakdown of animal species was done to enhance the knowledge of the make-up of floating material as part of a sea-turtle study (Plotkin and Amos, 1989) and was not directly part of this survey. The data are included here for comparison.

Figure 3.24 shows the pre- and post-MARPOL distribution of the vegetable material and includes **plastic** pieces as the most abundant form of litter collected and PMOW. The most important vegetable material and most abundant of all jetsam is the alga *Sargassum*, commonly referred to simply as the "weed". From year-to-year the frequency of occurrence and quantity

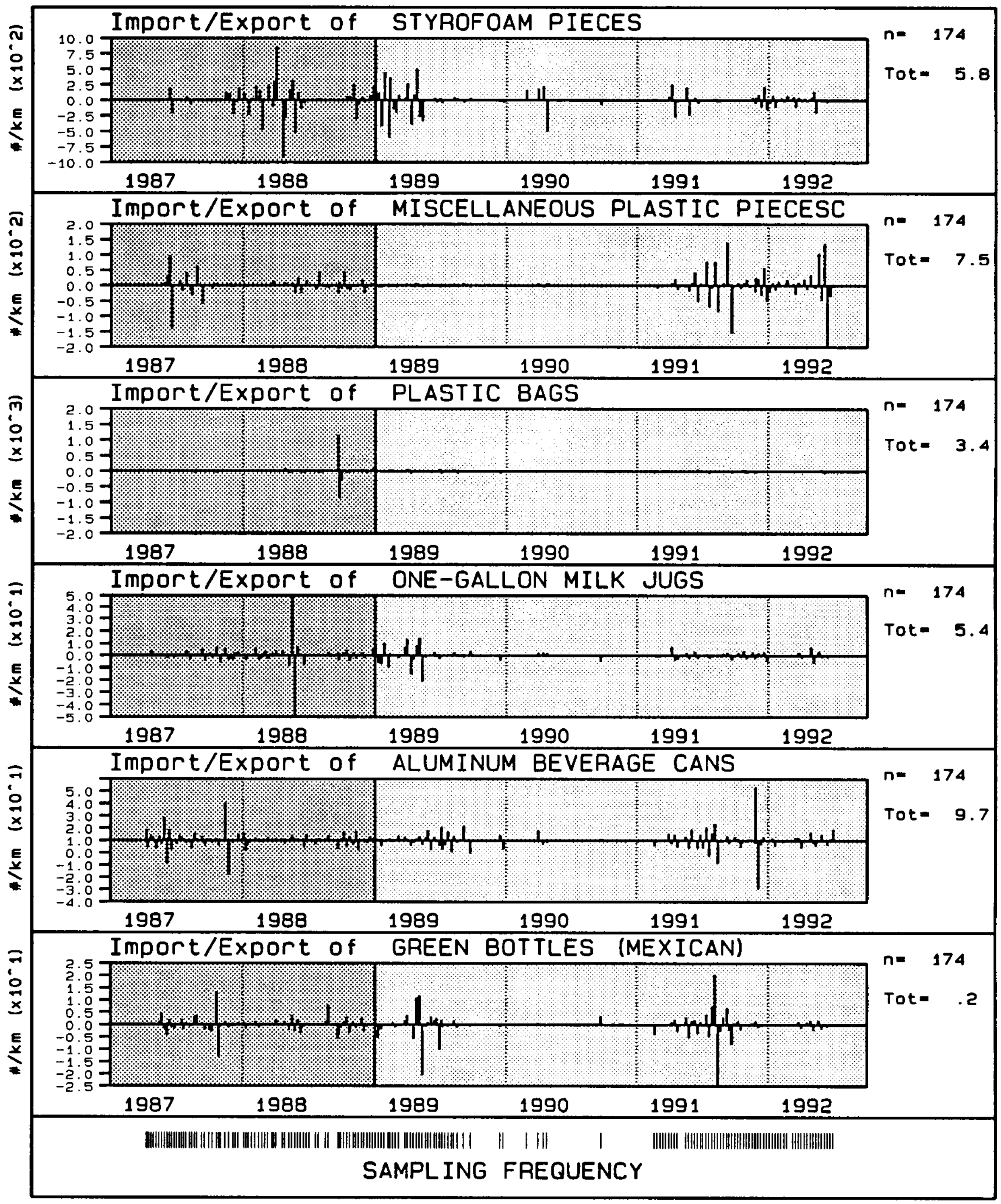


Figure 3.21. Import and Export of Debris: Common Litter Items Counted During GARBGobs.

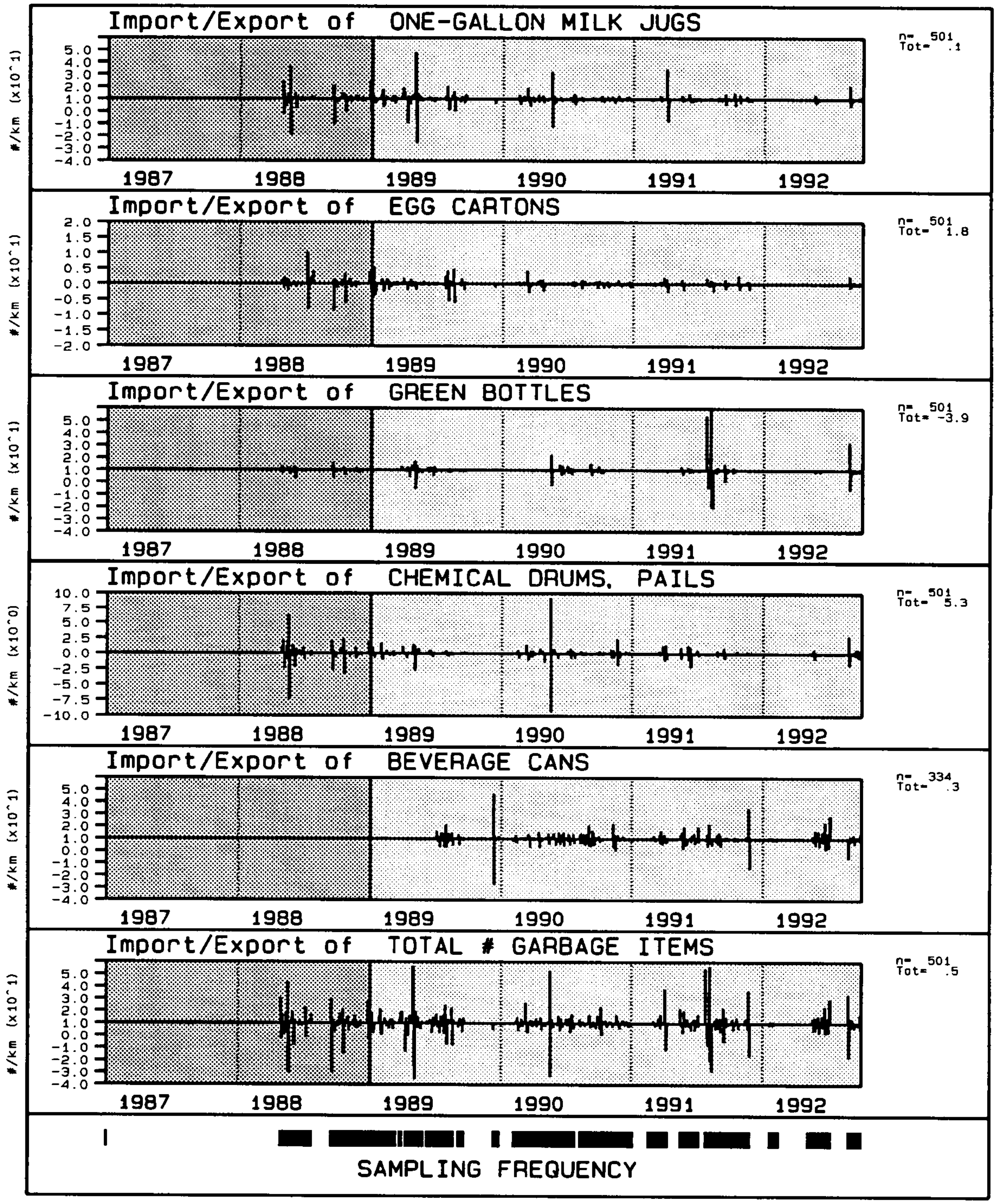


Figure 3.22. Import and Export of Debris: Five Indicator Items Counted on Bi-Daily Survey.

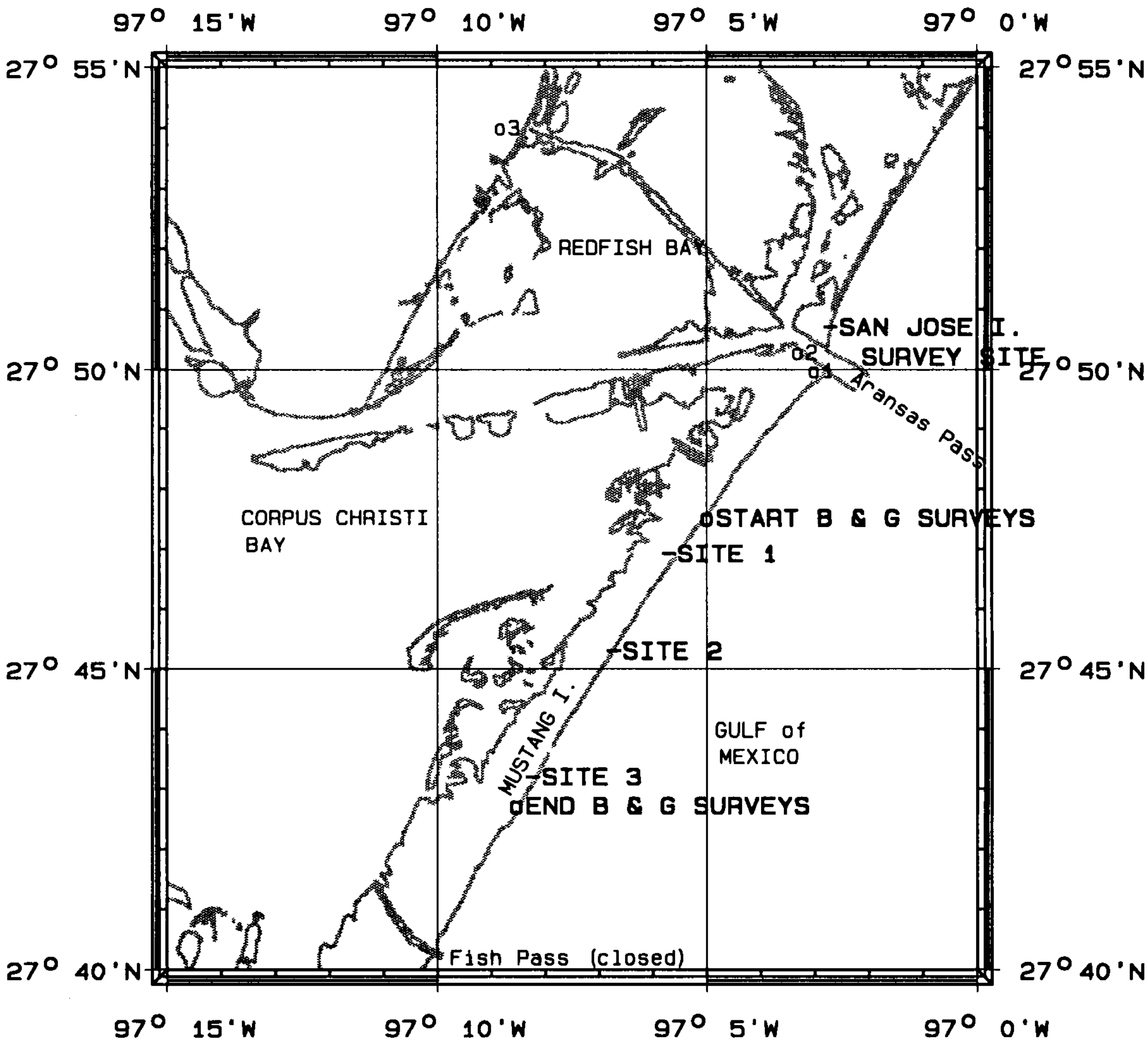


Figure 3.23. Location of Weekly Collection Sites on Mustang Island showing relation to Beach and Garbage (B & G) Survey transect.
1) UT Marine Science Institute
2) Port Aransas
3) Aransas Pass

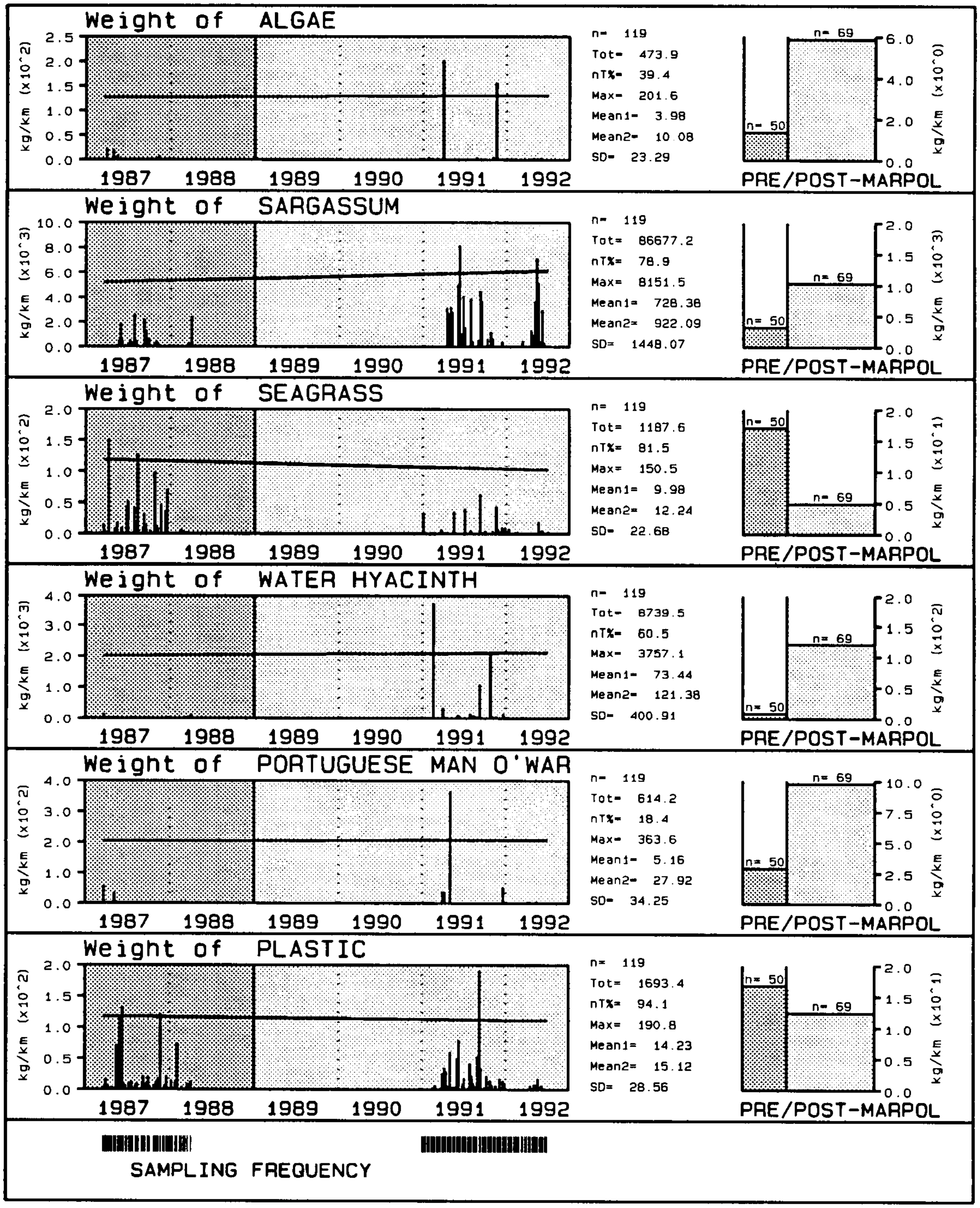


Figure 3.24. Results of Weekly Collections by Weight per Kilometer: Algae, Sargassum, Seagrass, Water Hyacinth, Portuguese Man-o-war, Plastic, Woody Vegetation, and Other Vegetation.

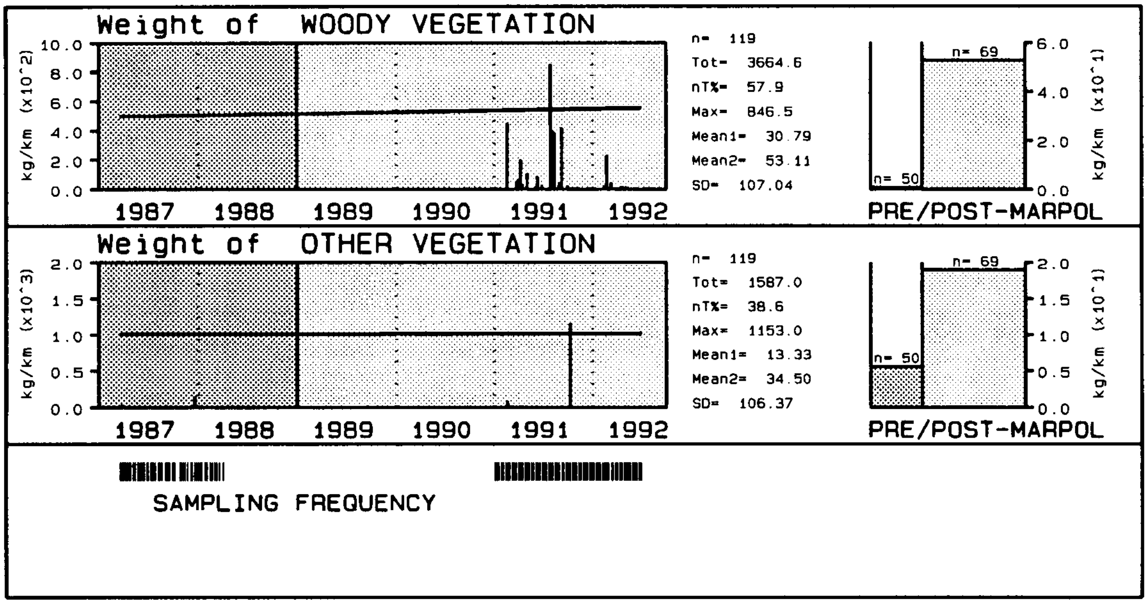


Figure 3.24. (cont.) Results of Weekly Collections by Weight per Kilometer: Algae, Sargassum, Seagrass, Water Hyacinth, Portuguese Man-o-war, Plastic, Woody Vegetation, and Other Vegetation.

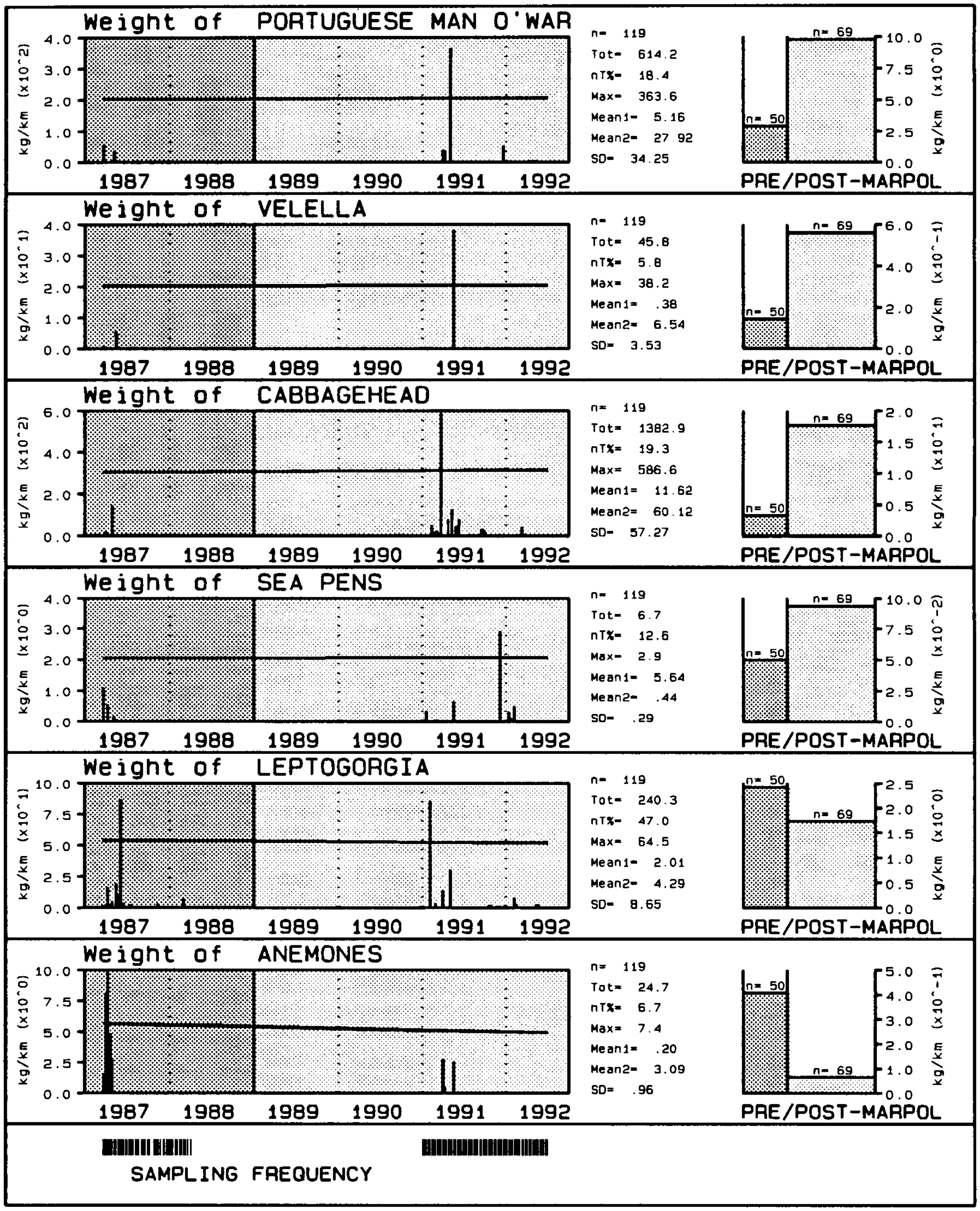


Figure 3.25. Results of Weekly Collections by Weight per Kilometer: Animals Collected.

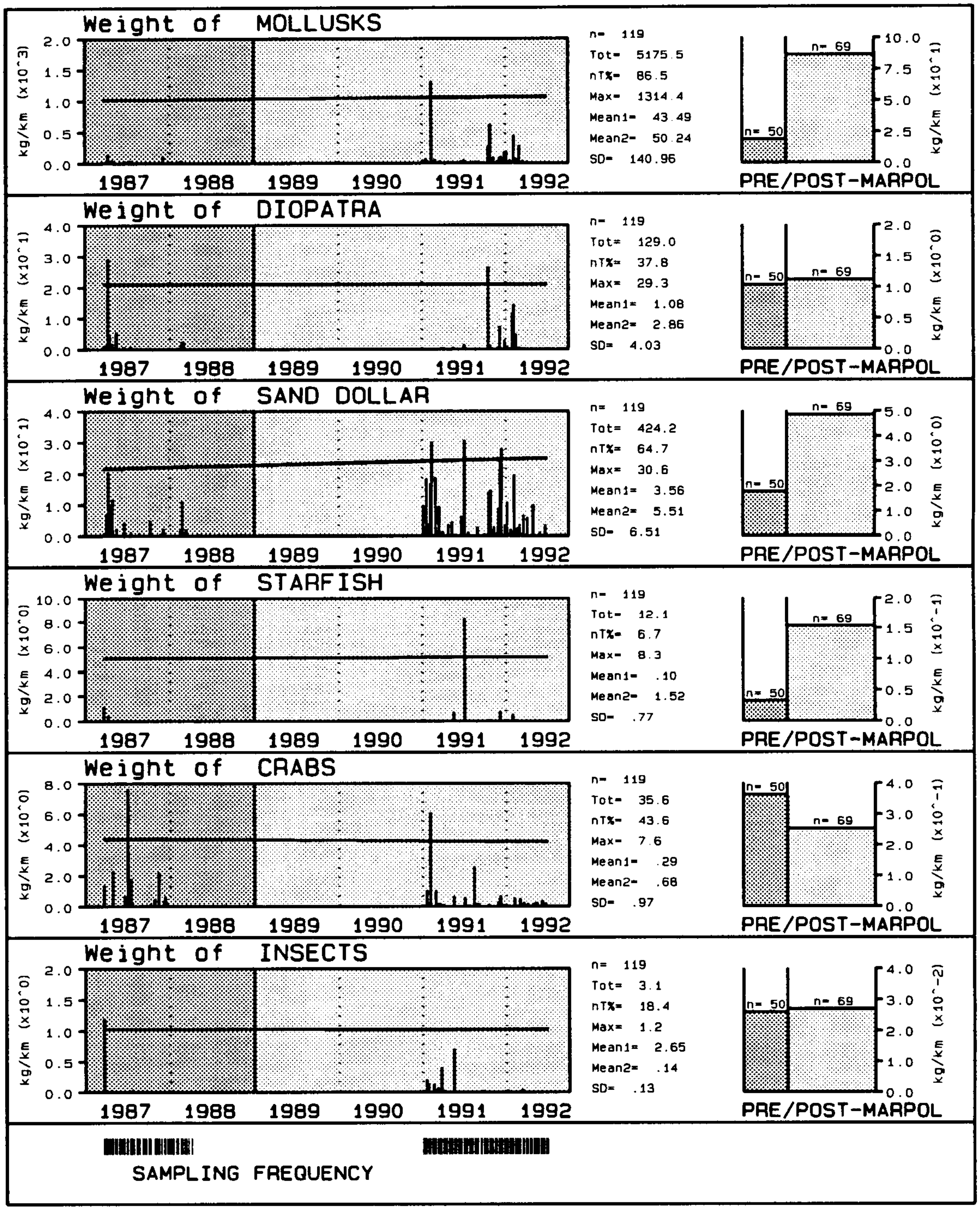


Figure 3.25. (cont) Results of Weekly Collections by Weight per Kilometer: Animals Collected.

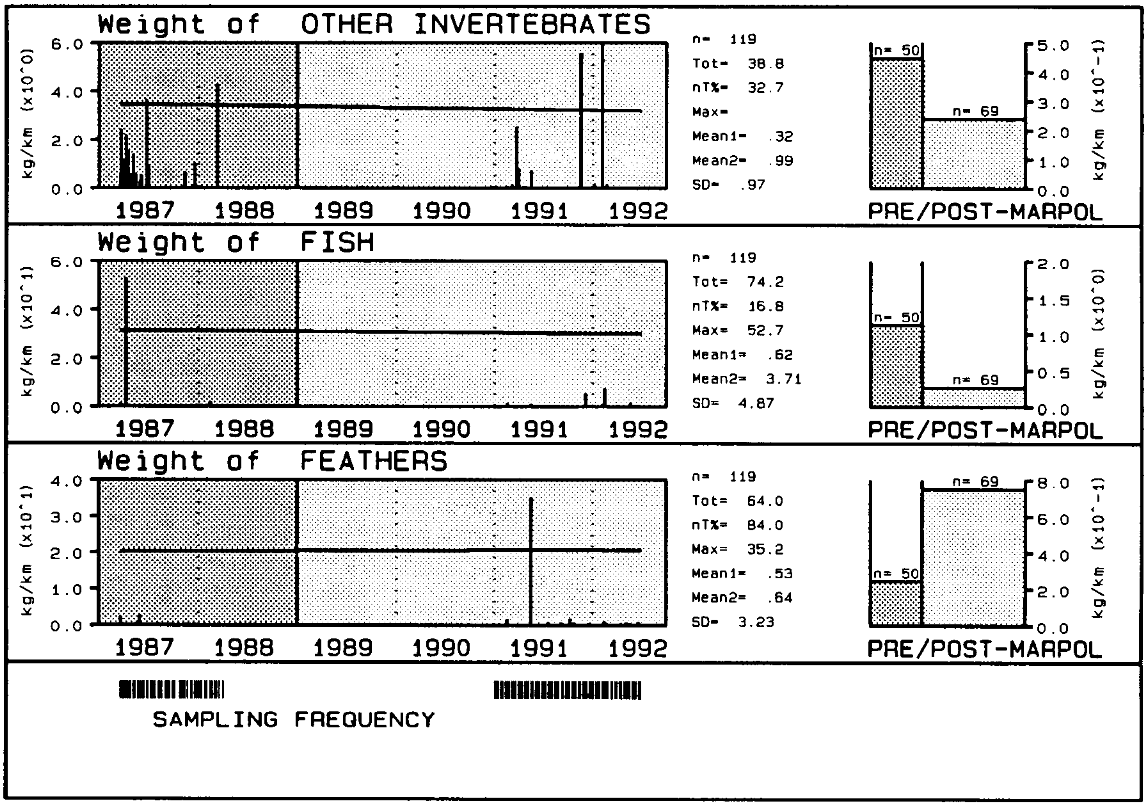


Figure 3.25. (cont.) Results of Weekly Collections by Weight per Kilometer: Animals Collected.

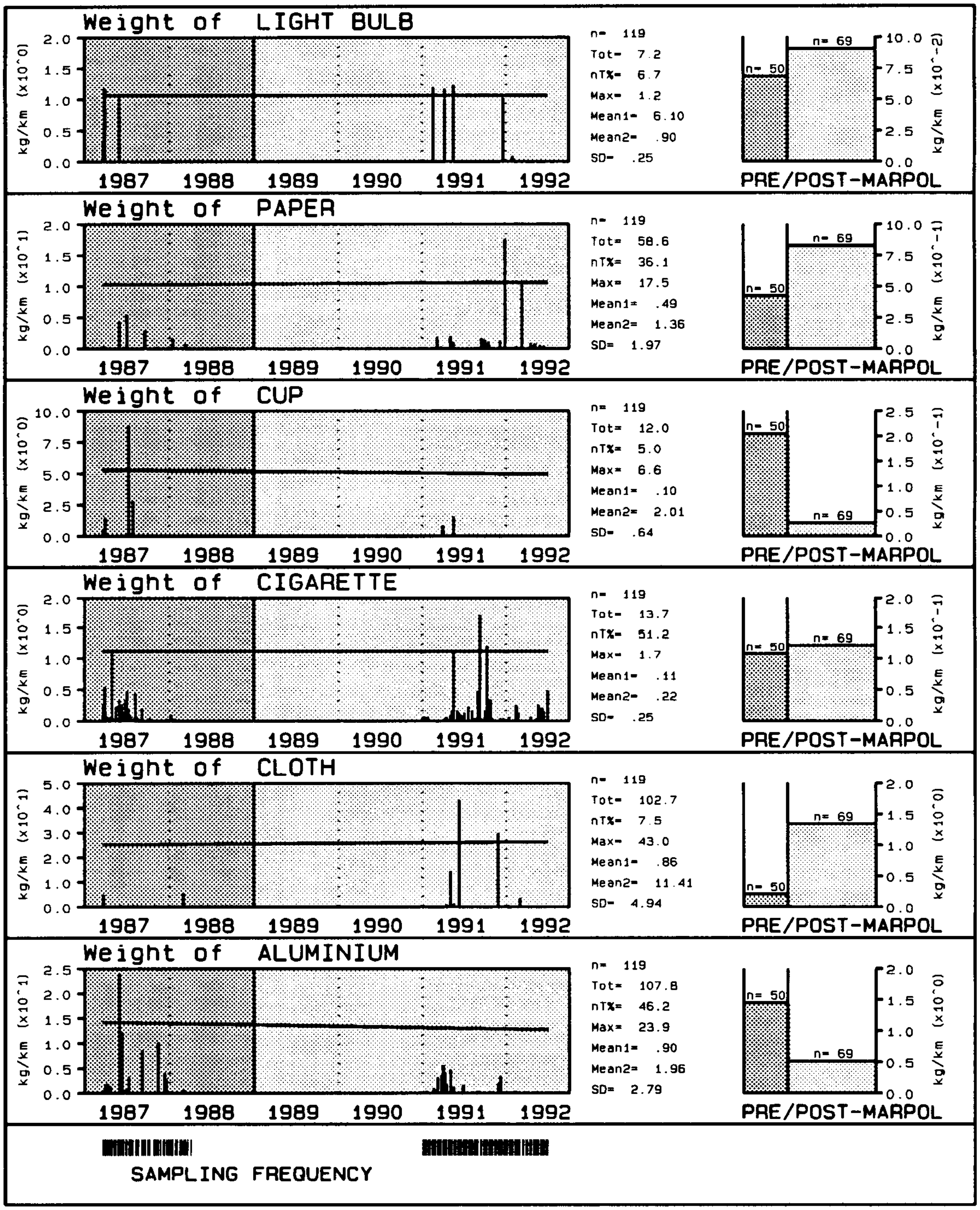


Figure 3.26. Results of Weekly Collections by Weight per Kilometer: Man-made Litter.

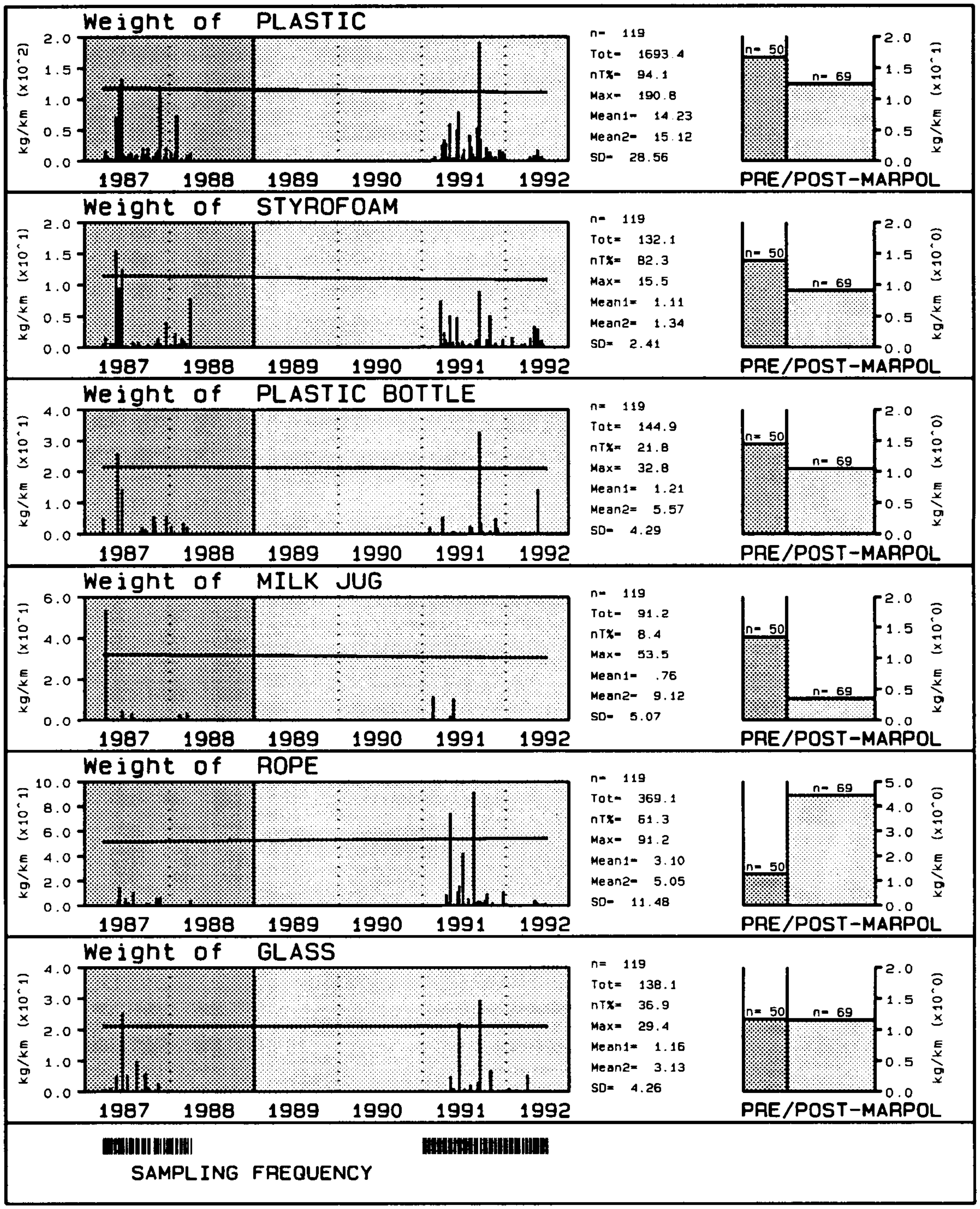


Figure 3.26. (cont.) Results of Weekly Collections by Weight per Kilometer: Man-made Litter.

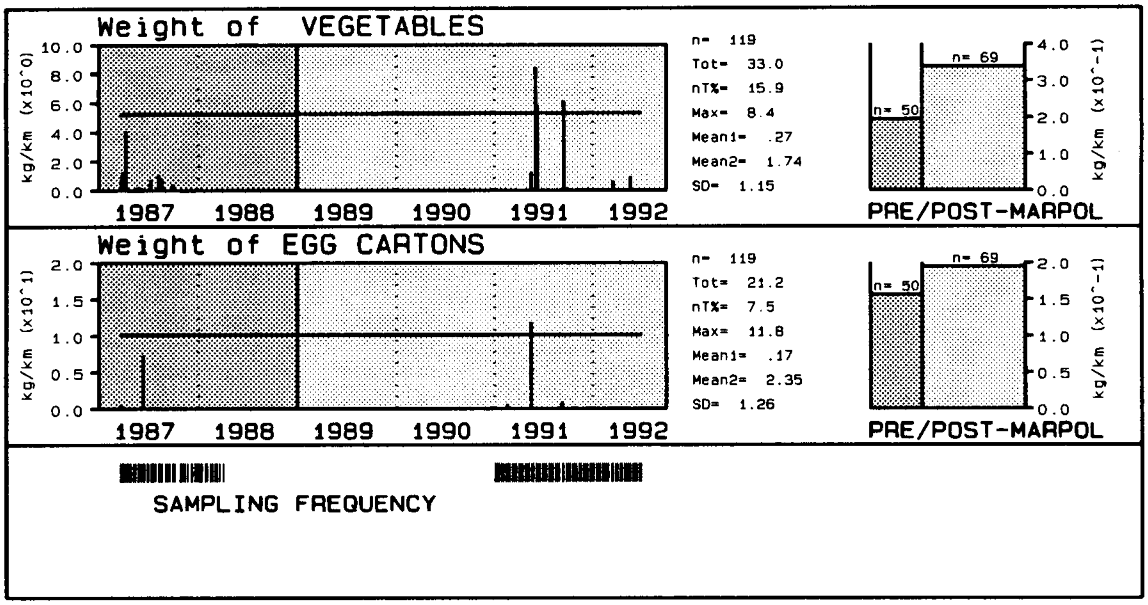


Figure 3.26. (cont.) Results of Weekly Collections by Weight per Kilometer: Man-made Litter.

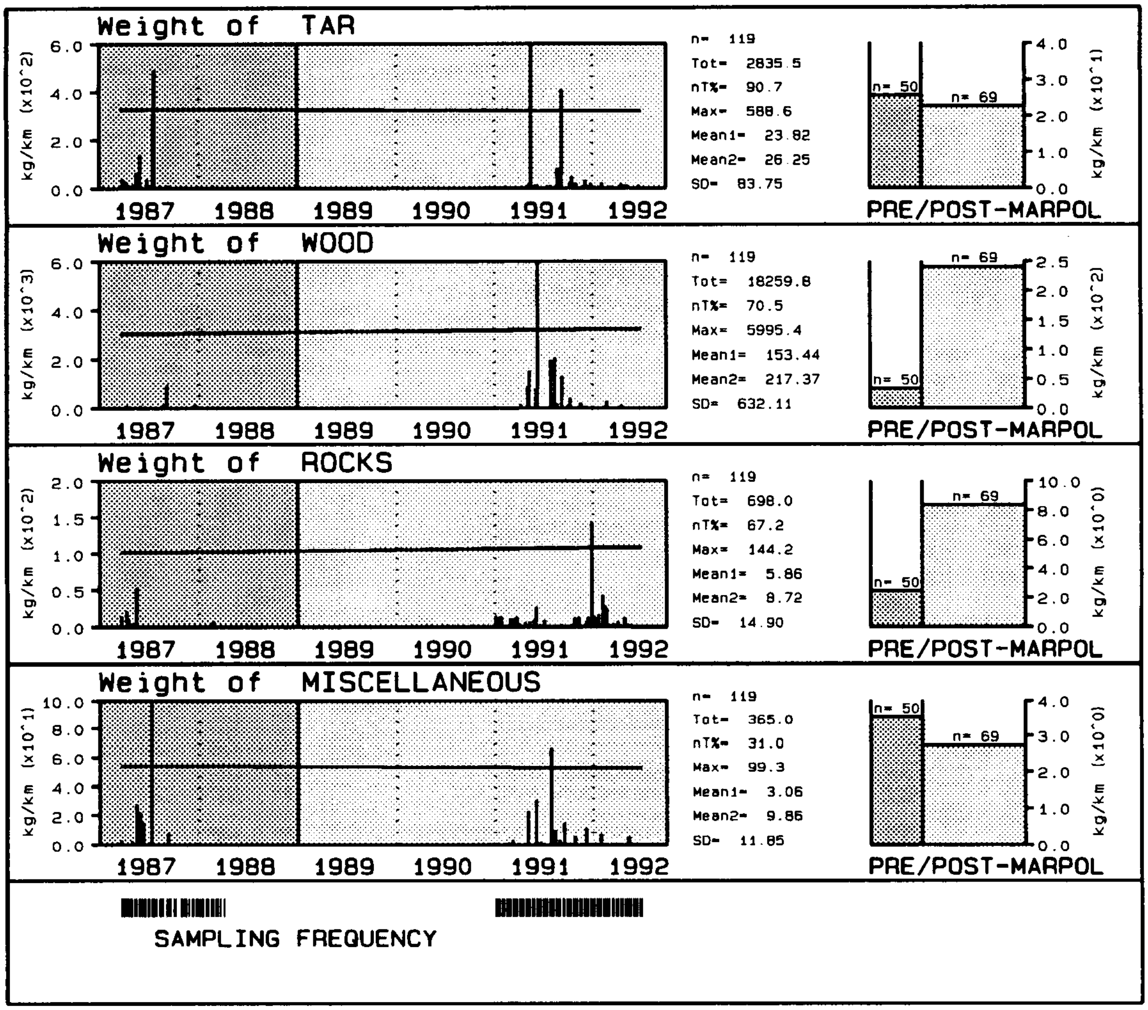


Figure 3.27. Results of Weekly Collections by Weight per Kilometer: Unknown Origin.

of weed on the beach varies considerably. Sometimes it is so thick that beach authorities mechanically remove it by grading the beach. There is an association at sea between weed and "trash" in the windrows and patches and, consequently, should be an association when the material is washed ashore. ***Sargassum*** was abundant in 1991 and 1992 but less-so in 1987-1988. At the same time the **plastic** decreased, contrary to expectations, but the PMOW increased. **Seagrasses**, which are only found in the bays, also decreased, but the terrestrial plant **water hyacinth**, which has its origin in rivers increased dramatically. **Woody vegetation**, also riverborne, and **other vegetation**, which may also come from rivers similarly increased.

Figure 3.25 illustrates the variation in the animals collected of which **PMOW**, **cabbagehead**, and **sea pens** are the most important. All increased post-MARPOL reflecting the general increase in natural debris in this period. Of the man-made litter collected (Figure 3.26), some items like **light bulbs** and **milk jug** are found singly in the survey areas and do not really count statistically in the analysis. Of the smaller items counted, the pre- and post-MARPOL quantities show variability, but the two major items, **plastic pieces** and **styrofoam**, have decreased. Items whose origin is not clear are illustrated in Figure 3.27. Pelagic **tar** has decreased on the beach. This has been noticeable not only by the measurements and estimates made by the author, but also by the beach-going public at large. A huge influx of driftwood in 1991 accounts for the post-MARPOL increase. This occurred along much of the Texas coast.

3.4 Ranking of Debris and Litter by Quantity and Weight

This section shows the relative importance of various items of debris and litter ranked by quantity and weight and frequency of occurrence on the Mustang Island survey beach. The section is divided into two parts; the "macro-litter" and natural debris as counted during GARBGobs, and the "micro-litter" and uncountable natural debris as weighed during the weekly collections.

3.4.1 Macro-Litter and Debris (by Quantity)

Each of the tables includes the "Top 50" out of the 73 categories of items which were deemed rankable. In this section, cars, people, dogs, and horses were included for comparison of numbers with other prominent "visitors" to the beach. Table 3.4 ranks the items by total counted. Also shown are the frequency of occurrence and the maximum number counted (per/km) on any one survey. A grand total of 394,429 items was counted during the 175 observations used in this analysis. Styrofoam pieces top the list with 102,520. In the top ten (excluding people), three natural debris items (PMOW, driftwood and cabbagehead jellyfish) occur and the rest are plastic items. It should be noted that most driftwood on this beach is the result of man's activities in clearing land or discarding lumber pieces. Ranked by the mean number of items per kilometer of beach (Table 3.5), the order changes little. Table 3.5 also lists the ranking pre- and post-MARPOL. The order changes little, but the post-MARPOL density is less for most of the litter but greater for driftwood and people visiting the beach. The number of observations was 75 pre-MARPOL and 100 post-MARPOL.

Table 3.4: Macro-Litter and Natural Debris Ranked by
Total Counted - All Observations

	Description of Item	Total	Freq	Max #/Km
1	Styrofoam pieces	102,520	99.4	993.42
2	Portuguese man-o-war	50,515	69.0	1,399.75
3	Plastic bags	49,031	99.4	1 179.88
4	Miscellaneous plastic piece	31,503	98.3	243.69
5	Driftwood	25,819	98.3	353.48
6	Plastic bottles	17,831	98.9	140.73
7	People	15,160	98.3	79.81
8	Cabbagehead jellyfish	10,659	62.1	136.02
9	Rope and hawsers	8,406	96.6	37.66
10	Lids (plastic)	7,818	96.0	40.49
11	Disposable drink cups	7,208	99.4	104.77
12	Glass bottles	7,184	93.7	39.78
13	Aluminum beverage cans	6,399	100.0	34.76
14	Pen shells	4,237	66.1	62.85
15	Plastic sheeting	4,059	92.0	21.31
16	Paper products	4,013	96.6	34.22
17	One-gallon milk jugs	3,879	90.8	50.46
18	Automobiles	3,717	97.7	23.38
19	Egg cartons	3,505	90.2	15.72
20	Green bottles (mexican)	2,869	81.0	27.83
21	Gloves	2,399	87.4	18.94
22	Cans (not beverage cans)	2,358	88.5	11.91
23	Six-pack rings	2,279	86.2	26.12
24	Lightbulbs	1,768	82.2	12.55
25	Light sticks	1,702	66.1	36.85
26	Foam (not styrofoam)	1,539	85.6	5.67
27	Shoes	1,229	80.5	10.36
28	Cardboard cartons	1,203	86.2	4.45
29	Fruit	1,197	82.8	7.94
30	Camped people	1,137	66.7	20.85
31	Plastic strapping	1,090	56.3	8.60
32	Dead fish	1,074	77.6	12.68
33	Produce sacks	1,016	85.1	5.84
34	Dead crabs	888	66.1	11.47
35	Camped cars	797	72.4	12.91
36	Balloons	722	68.4	7.08
37	Outboard motor oil	682	55.2	10.85
38	Fishing and seismic floats	601	73.6	3.29
39	Sea beans	540	10.9	21.54
40	5-Gal plastic pails	524	60.3	6.97
41	Fluorescent tubes	519	56.3	5.19
42	Vegetables	499	62.1	4.28
43	Cloth and clothing	487	70.7	3.80
44	Spent fireworks	485	12.1	27.15
45	Fishing line	481	64.9	4.69
46	Miscellaneous metal pieces	407	73.0	2.48
47	Coconuts	353	37.9	3.65
48	Horses	340	21.3	2.36
49	Dogs	323	65.5	1.67
50	Disposable lighters	320	62.1	2.34
	Total	394,429	100.0	

Table 3.5: Macro-Litter and Debris Ranked by Mean Number Per Kilometer

	All Obs		Pre-MARPOL		Post-MARPOL	
	Item	Mean/km	Item	Mean/km	Item	mean/km
1	Styrofoam pieces	73.12	Styrofoam pieces	86.08	Styrofoam pieces	63.54
2	Portuguese man-o-war	35.17	Plastic bags	51.64	Portuguese man-o-war	23.20
3	Plastic bags	35.07	Portuguese man-o-war	51.35	Plastic bags	22.80
4	Misc. Plastic pcs.	19.19	Miscellaneous plastic pcs.	16.30	Miscellaneous plastic pcs.	21.34
5	Driftwood	16.22	Driftwood	15.43	Driftwood	16.79
6	Plastic bottles	12.32	Plastic bottles	12.00	Plastic bottles	12.56
7	People	8.44	Cabbagehead jellyfish	7.84	People	9.65
8	Cabbagehead jellyfish	6.34	Disposable drink cups	7.04	Cabbagehead jellyfish	5.23
9	Rope and hawsers	5.64	Lids (plastic)	6.89	Rope and hawsers	5.11
10	Lids (plastic)	5.25	People	6.80	Glass bottles	4.46
11	Glass bottles	5.08	Rope and hawsers	6.36	Lids (plastic)	4.03
12	Disposable drink cups	5.03	Glass bottles	5.91	Aluminum beverage cans	3.91
13	Aluminum beverage cans	4.04	Pen shells	5.42	Disposable drink cups	3.55
14	Pen shells	2.87	Plastic sheeting	4.43	Paper products	2.89
15	One-gallon milk jugs	2.83	Aluminum beverage cans	4.22	One-gallon milk jugs	2.46
16	Paper products	2.39	One-gallon milk jugs	3.33	Automobiles	2.28
17	Plastic sheeting	2.34	Egg cartons	2.99	Green bottles (mexican)	2.08
18	Egg cartons	2.32	Six-pack rings	2.51	Egg cartons	1.83
19	Automobiles	2.20	Light sticks	2.19	Cans (not beverage cans)	1.48
20	Green bottles (mexican)	1.93	Automobiles	2.08	Gloves	1.35
21	Cans (not beverage cans)	1.67	Cans (not beverage cans)	1.93	Lightbulbs	1.17
22	Six-pack rings	1.62	Gloves	1.79	Camped people	1.03
23	Gloves	1.53	Green bottles (mexican)	1.73	Pen shells	0.99
24	Light sticks	1.35	Paper products	1.72	Six-pack rings	0.97
25	Lightbulbs	1.30	Lightbulbs	1.47	Foam (not styrofoam)	0.94
26	Foam (not styrofoam)	1.00	Foam (not styrofoam)	1.08	Plastic strapping	0.93
27	Camped people	0.00	Cardboard cartons	1.00	Plastic sheeting	0.79
28	Plastic strapping	0.83	Shoes	0.97	Camped cars	0.78
29	Shoes	0.81	Dead crabs	0.91	Dead fish	0.74
30	Cardboard cartons	0.80	Fruit	0.85	Fruit	0.74
31	Fruit	0.79	Plastic strapping	0.69	Produce sacks	0.74
32	Produce sacks	0.65	Camped people	0.63	Light sticks	0.73
33	Dead fish	0.65	Produce sacks	0.54	Shoes	0.69
34	Camped cars	0.00	Dead fish	0.53	Cardboard cartons	0.65
35	Dead crabs	0.54	Balloons	0.51	Outboard motor oil	0.59
36	Balloons	0.53	5-Gal plastic pails	0.50	Sea beans	0.54
37	Outboard motor oil	0.48	Fishing line	0.46	Balloons	0.54
38	Fishing and seismic floats	0.42	Fishing/seismic floats	0.43	Spent fireworks	0.44
39	5-Gal plastic pails	0.39	Cloth and clothing	0.39	Fishing and seismic floats	0.42
40	Fluorescent tubes	0.37	Vegetables	0.39	Fluorescent tubes	0.37
41	Fishing line	0.34	Fluorescent tubes	0.38	Coconuts	0.34
42	Vegetables	0.34	Misc. Metal pieces	0.37	Vegetables	0.31
43	Sea beans	0.32	Camped cars	0.35	5-Gal plastic pails	0.30
44	Cloth and clothing	0.31	Outboard motor oil	0.34	Dead crabs	0.26
45	Spent fireworks	0.28	Disposable lighters	0.30	Fishing line	0.25
46	Miscellaneous metal pieces	0.27	Write-protect rings	0.21	Cloth and clothing	0.25
47	Coconuts	0.25	Tubes of grease	0.17	Dogs	0.24
48	Disposable lighters	0.22	Toys	0.16	Dead bird	0.23
49	Dogs	0.00	Reels (cable; line)	0.16	Toys	0.20
50	Toys	0.19	Dogs	0.15	Miscellaneous metal pieces	0.19

Table 3.6: Macro-Litter and Debris Ranked by Frequency

	All Obs Item	Freq	Pre-MARPOL Item	Freq	Post-MARPOL Item	Freq
1	Aluminum beverage cans	100.0	Aluminum beverage cans	100.0	Aluminum beverage cans	100.0
2	Plastic bags	99.4	Styrofoam pieces	100.0	Plastic bags	100.0
3	Styrofoam pieces	99.4	Plastic sheeting	100.0	People	99.0
4	Disposable drink cups	99.4	Disposable drink cups	100.0	Styrofoam pieces	99.0
5	Plastic bottles	98.9	Plastic bottles	100.0	Disposable drink cups	99.0
6	People	98.3	Paper products	98.6	Automobiles	98.0
7	Miscellaneous plastic pcs.	98.3	Plastic bags	98.6	Miscellaneous plastic pcs.	98.0
8	Driftwood	98.3	Miscellaneous plastic pcs.	98.6	Plastic bottles	98.0
9	Automobiles	97.7	Driftwood	98.6	Driftwood	98.0
10	Paper products	96.6	People	97.3	Rope and hawsers	97.0
11	Rope and hawsers	96.6	Automobiles	97.3	Lids (plastic)	95.0
12	Lids (plastic)	96.0	Lids (plastic)	97.3	Paper products	95.0
13	Glass bottles	93.7	Egg cartons	95.9	Glass bottles	93.0
14	Plastic sheeting	92.0	Rope and hawsers	95.9	One-gallon milk jugs	88.0
15	One-gallon milk jugs	90.8	Glass bottles	94.6	Egg cartons	86.0
16	Egg cartons	90.2	One-gallon milk jugs	94.6	Produce sacks	86.0
17	Cans (not beverage cans)	88.5	Gloves	93.2	Plastic sheeting	86.0
18	Gloves	87.4	Cans (not beverage cans)	93.2	Cans (not beverage cans)	85.0
19	Six-pack rings	86.2	Cardboard cartons	93.2	Gloves	83.0
20	Cardboard cartons	86.2	Six-pack rings	90.5	Six-pack rings	83.0
21	Foam (not styrofoam)	85.6	Foam (not styrofoam)	89.2	Foam (not styrofoam)	83.0
22	Produce sacks	85.1	Lightbulbs	87.8	Cardboard cartons	81.0
23	Fruit	82.8	Fruit	86.5	Fruit	80.0
24	Lightbulbs	82.2	Green bottles (mexican)	85.1	Shoes	79.0
25	Green bottles (mexican)	81.0	Miscellaneous metal pieces	85.1	Green bottles (mexican)	78.0
26	Shoes	80.5	Produce sacks	83.8	Lightbulbs	78.0
27	Dead fish	77.6	Pen shells	83.8	Plastic strapping	76.0
28	Fishing and seismic floats	73.6	Shoes	82.4	Dead fish	75.0
29	Miscellaneous metal pieces	73.0	Cloth and clothing	82.4	Camped cars	73.0
30	Camped cars	72.4	Dead fish	81.1	Balloons	73.0
31	Cloth and clothing	70.7	Dead crabs	79.7	Dogs	72.0
32	Portuguese man-o-war	69.0	Fishing line	77.0	Fishing and seismic floats	71.0
33	Balloons	68.4	Fishing and seismic floats	77.0	Portuguese man-o-war	67.0
34	Camped people	66.7	Camped cars	71.6	Camped people	64.0
35	Light sticks	66.1	Light sticks	71.6	Miscellaneous metal pieces	64.0
36	Pen shells	66.1	Portuguese man-o-war	71.6	Outboard motor oil	63.0
37	Dead crabs	66.1	Camped people	70.3	Light sticks	62.0
38	Dogs	65.5	Vegetables	67.6	Cloth and clothing	62.0
39	Fishing line	64.9	5-Gal plastic pails	66.2	Cabbagehead jellyfish	62.0
40	Vegetables	62.1	Disposable lighters	64.9	Disposable lighters	60.0
41	Cabbagehead jellyfish	62.1	Fluorescent tubes	63.5	Vegetables	58.0
42	Disposable lighters	62.1	Balloons	62.2	5-Gal plastic pails	56.0
43	5-Gal plastic pails	60.3	Cabbagehead jellyfish	62.2	Fishing line	56.0
44	Plastic strapping	56.3	Dogs	56.8	Dead crabs	56.0
45	Fluorescent tubes	56.3	Tubes of grease	52.7	Pen shells	53.0
46	Outboard motor oil	55.2	Reels (cable;fishing line)	51.4	Dead bird	53.0
47	Toys	46.6	Toys	45.9	Coconuts	52.0
48	Tubes of grease	44.8	Write-protect rings	44.6	Fluorescent tubes	51.0
49	Fishing nets	42.5	Outboard motor oil	44.6	Toys	47.0
50	Dead bird	38.5	Fishing nets	40.5	Fishing nets	44.0

Table 3.6 ranks the data by frequency of occurrence (expressed as a percentage) on the beach. The ranking order changes considerably as all but driftwood in the natural debris category drop out of the top-30 reflecting the seasonality of these beachings compared to the more constant input of man-made litter. Note that pre-MARPOL, several items were encountered on every survey but post-MARPOL only beverage cans are 100% present and these are almost always left by beachgoers. Not only has the density of litter decreased but so has its frequency since MARPOL. Some litter items (e.g. plastic bags) have increased in frequency. The percentage of plastics in the total of man-made items has changed very little as illustrated in Table 3.7.

3.4.2 **Micro-Litter and Uncountable Debris (by Weight)**

Table 3.8 ranks the micro-litter and other debris by total weight in the 118 observations made both before and after MARPOL. Of the eleven man-made items commonly found, only plastic (pieces) appears in the top-10. Over 50 kg of plastic fragments were collected. Compare this to the 2,600 kg of *Sargassum* weighed (or in exceptionally heavy weed days, a measured section was weighed and the total weight then estimated by blocking). Comparing the extrapolated weights per kilometer ranked in Table 3.9, plastic pieces dropped from fourth pre-MARPOL to eighth post-MARPOL. 1991-1992 saw heavy beachings of *Sargassum*, driftwood, and terrestrial vegetation, yet the overall concentration of plastic pieces was down from the 1987-1988 period of the pre-MARPOL measurements.

Table 3.7: Percentage of Plastic Among the Micro-Litter

	All Obs n=175		Pre-MARPOL n=75		Post-MARPOL n=100	
	Total #	%	Total #	%	Total #	%
Plastic items	245,662	**87.1**	124,031	**87.4**	121,233	**86.6**
Other items	32,830	12.9	17,748	12.5	18,732	13.4
Natural items	*94,298*		*53,835*		*40,463*	

Table 3.8: Micro-Litter and Uncountable Debris Ranked By Total Weighed - All Observations

	Description of Item	Total(kg)	Freq	Max(kg)
1	Sargassum	2600.32	79.7	244.545
2	Wood	547.80	71.2	179.863
3	Water hyacinth	262.19	61.0	112.715
4	Mollusks	155.27	87.3	39.432
5	Woody vegetation	109.94	58.5	25.395
6	Tar	85.07	91.5	17.659
7	Plastic	50.80	94.9	5.724
8	Other vegetation	47.61	39.0	34.591
9	Cabbagehead	41.49	19.5	17.600
10	Seagrass	35.63	82.2	4.517
11	Rocks	20.94	67.8	4.326
12	Portuguese man-o-war	18.43	18.6	10.908
13	Algae	14.22	39.8	6.048
14	Sand dollar	12.73	65.3	0.919
15	Rope	11.08	61.9	2.736
16	Miscellaneous	10.95	31.4	2.979
17	Leptogorgia	7.21	47.5	1.936
18	Sea bean	5.05	33.1	1.557
19	Plastic bottle	4.35	22.0	0.986
20	Glass	4.14	37.3	0.882
21	Styrofoam	3.97	83.1	0.465
22	Diopatra	3.87	38.1	0.879
23	Aluminium	3.23	46.6	0.718
24	Cloth	3.08	7.6	1.292
25	Milk jug	2.74	8.5	1.607
26	Fish	2.23	16.9	1.583
27	Feathers	1.92	84.7	1.058
28	Paper	1.76	36.4	0.527
29	Velella	1.37	5.9	1.146
30	Other invertebrates	1.17	33.1	0.180
31	Crabs	1.07	44.1	0.229
32	Vegetables	0.99	16.1	0.252
33	Anemones	0.74	6.8	0.224
34	Egg	0.64	7.6	0.354
35	Cigarette	0.41	51.7	0.051
36	Starfish	0.36	6.8	0.249
37	Cup	0.36	5.1	0.199
38	Light bulb	0.22	6.8	0.037
39	Mangrove seed	0.21	11.9	0.070
40	Sea pens	0.20	12.7	0.087
41	Insects	0.09	18.6	0.036

Table 3.9: Micro-Litter and Uncountable Debris Ranked By Weight per Kilometer

	All Obs		Pre-MARPOL		Post-MARPOL	
	Item	kg/km	Item	kg/km	Item	kg/km
1	Sargassum	734.55	Sargassum	322.24	Sargassum	1,027.34
2	Wood	154.74	Wood	33.83	Wood	240.61
3	Water hyacinth	74.06	Tar	26.08	Water hyacinth	120.53
4	Mollusks	43.86	Seagrass	17.37	Mollusks	64.78
5	Woody vegetation	31.06	Plastic	17.11	Woody vegetation	52.56
6	Tar	24.03	Mollusks	14.40	Tar	22.58
7	Plastic	14.35	Water hyacinth	8.63	Other vegetation	18.97
8	Other vegetation	13.45	Other vegetation	5.68	Cabbagehead	17.66
9	Cabbagehead	11.72	Miscellaneous	3.61	Plastic	12.40
10	Seagrass	10.07	Cabbagehead	3.36	Rocks	8.35
11	Rocks	5.92	Rocks	2.49	Portuguese man-o-war	7.33
12	Portuguese man-o-war	5.21	Leptogorgia	2.47	Algae	5.87
13	Algae	4.02	Portuguese man-o-war	2.21	Seagrass	4.88
14	Sand dollar	3.60	Sand dollar	1.81	Sand dollar	4.86
15	Rope	3.13	Plastic bottle	1.48	Rope	4.43
16	Miscellaneous	3.09	Aluminium	1.48	Miscellaneous	2.73
17	Leptogorgia	2.04	Styrofoam	1.42	Sea bean	2.37
18	Sea bean	1.43	Algae	1.40	Leptogorgia	1.73
19	Plastic bottle	1.23	Milk jug	1.38	Cloth	1.34
20	Glass	1.17	Rope	1.29	Glass	1.16
21	Styrofoam	1.12	Glass	1.19	Diopatra	1.12
22	Diopatra	1.09	Fish	1.14	Plastic bottle	1.05
23	Aluminium	0.91	Diopatra	1.06	Styrofoam	0.91
24	Cloth	0.87	Woody vegetation	0.77	Feathers	0.75
25	Milk jug	0.77	Other invertebrates	0.46	Paper	0.62
26	Fish	0.63	Anemones	0.42	Velella	0.56
27	Feathers	0.54	Crabs	0.37	Aluminium	0.51
28	Paper	0.50	Paper	0.32	Milk jug	0.34
29	Velella	0.39	Feathers	0.25	Vegetables	0.34
30	Other invertebrates	0.33	Cloth	0.21	Fish	0.26
31	Crabs	0.30	Cup	0.21	Crabs	0.25
32	Vegetables	0.28	Vegetables	0.20	Other invertebrates	0.24
33	Anemones	0.21	Egg	0.16	Egg	0.19
34	Egg	0.18	Velella	0.15	Starfish	0.15
35	Cigarette	0.12	Cigarette	0.11	Cigarette	0.12
36	Starfish	0.10	Sea bean	0.10	Sea pens	0.07
37	Cup	0.10	Mangrove seed	0.06	Light bulb	0.07
38	Light bulb	0.06	Light bulb	0.05	Anemones	0.06
39	Mangrove seed	0.06	Sea pens	0.04	Mangrove seed	0.06
40	Sea pens	0.06	Starfish	0.03	Insects	0.03
41	Insects	0.03	Insects	0.03	Cup	0.03

Table 3.10: Micro-Litter and Uncountable Debris Ranked By Frequency

	All Obs Item	Freq	Pre-MARPOL Item	Freq	Post-MARPOL Item	Freq
1	Plastic	94.9	Plastic	98.0	Tar	92.8
2	Tar	91.5	Tar	89.8	Plastic	92.8
3	Mollusks	87.3	Seagrass	83.7	Rocks	91.3
4	Feathers	84.7	Wood	81.6	Mollusks	91.3
5	Styrofoam	83.1	Styrofoam	81.6	Feathers	87.0
6	Seagrass	82.2	Feathers	81.6	Styrofoam	84.1
7	Sargassum	79.7	Mollusks	81.6	Woody vegetation	81.2
8	Wood	71.2	Sargassum	79.6	Seagrass	81.2
9	Rocks	67.8	Cigarette	53.1	Sargassum	79.7
10	Sand dollar	65.3	Other vegetation	51.0	Sand dollar	78.3
11	Rope	61.9	Water hyacinth	51.0	Rope	71.0
12	Water hyacinth	61.0	Rope	49.0	Water hyacinth	68.1
13	Woody vegetation	58.5	Leptogorgia	49.0	Wood	63.8
14	Cigarette	51.7	Sand dollar	46.9	Crabs	56.5
15	Leptogorgia	47.5	Aluminium	40.8	Aluminium	50.7
16	Aluminium	46.6	Other invertebrates	40.8	Cigarette	50.7
17	Crabs	44.1	Diopatra	36.7	Sea bean	49.3
18	Algae	39.8	Rocks	34.7	Algae	47.8
19	Other vegetation	39.0	Algae	28.6	Leptogorgia	46.4
20	Diopatra	38.1	Glass	26.5	Paper	44.9
21	Glass	37.3	Crabs	26.5	Glass	44.9
22	Paper	36.4	Woody vegetation	26.5	Diopatra	39.1
23	Other invertebrates	33.1	Vegetables	24.5	Miscellaneous	37.7
24	Sea bean	33.1	Paper	24.5	Other vegetation	30.4
25	Miscellaneous	31.4	Plastic bottle	24.5	Other invertebrates	27.5
26	Plastic bottle	22.0	Mangrove seed	24.5	Cabbagehead	27.5
27	Cabbagehead	19.5	Miscellaneous	22.4	Insects	26.1
28	Insects	18.6	Portuguese man-o-war	16.3	Fish	21.7
29	Portuguese man-o-war	18.6	Milk jug	12.2	Plastic bottle	20.3
30	Fish	16.9	Fish	10.2	Portuguese man-o-war	20.3
31	Vegetables	16.1	Anemones	10.2	Sea pens	14.5
32	Sea pens	12.7	Sea pens	10.2	Vegetables	10.1
33	Mangrove seed	11.9	Velella	10.2	Cloth	10.1
34	Milk jug	8.5	Sea bean	10.2	Starfish	8.7
35	Egg	7.6	Egg	8.2	Egg	7.2
36	Cloth	7.6	Cup	8.2	Light bulb	7.2
37	Light bulb	6.8	Insects	8.2	Milk jug	5.8
38	Starfish	6.8	Cabbagehead	8.2	Anemones	4.3
39	Anemones	6.8	Light bulb	6.1	Cup	2.9
40	Velella	5.9	Cloth	4.1	Velella	2.9
41	Cup	5.1	Starfish	4.1	Mangrove seed	2.9

How did the frequency of beaching of micro-litter compare with the larger material? Table 3.10 shows that plastic pieces were consistently the most frequently found material among the beach-wrack followed closely by pelagic tar. Styrofoam pieces were the fifth most commonly occurring of the 41 items identified in the weekly collections of beach debris. Plastic pieces were found less frequently after MARPOL but styrofoam was more frequent. These few percentage points however are probably not significant. In Table 3.11, the percentage of plastic micro-litter to the other man-made material is almost exactly the same as with the larger items counted during GARBGobs.

Table 3.11: Percentage By Weight of Plastic Among the Micro-Litter

	All Obs n=118		Pre-MARPOL n=49		Post-MARPOL n=69	
	Total kg	%	Total kg	%	Total kg	%
Plastic Items	86.12	**84.7**	38.58	**87.6**	47.54	**83.8**
Other Items	13.18	15.3	4.79	12.4	7.69	16.2
Natural items	*3987.81*		*662.09*		*3289.85*	

3.5 Litter (Containers) By Quantity, Size, Material, and Country of Origin

A 250-m stretch of San Jose Island was chosen just north of the north jetty of the Aransas Pass Channel as a site to collect containers on the beach. Other litter items were ignored. The study was conducted monthly from June 1991 through August 1992. Access to the beach was by boat. All containers (plastic bottles, jugs and pails, beverage cans, glass bottles and cardboard cartons) found on the beach from shoreline to dune line were collected, bagged and brought back by boat to the laboratory. There they were examined and classified for material, volume, weight, color and country of origin. The material classification is as follows: plastic, beverage (aluminum), glass, other can ("tin" food cans, etc.) and cardboard.

3.5.1 Number of Containers by Type

As expected, the first month's collection netted the largest total of containers (648). San Jose Island is not cleaned and litter collects there until some event (storm, high tide, wind, [litter study]) removes or redistributes them. The histograms in Figure 3.29 show the relative proportions of each container type for each month. In general plastic dominates but beverage cans form a significant proportion of the containers. That proportion is less during the winter indicating that the source is most likely from recreational boats or visitors to this beach. Visitors must come via the "Jetty Boat" from Port Aransas and generally do not carry much equipment with them. Table 3.12 lists the numbers collected and the percentages of each material type for each collection.

Figures 3.28 through 3.33 show the monthly totals for each container type by material. Plastic container numbers (Figure 3.29) dropped dramatically after the initial collection in June 1991 but from September 1991 through January 1992, monthly accumulations increased to nearly

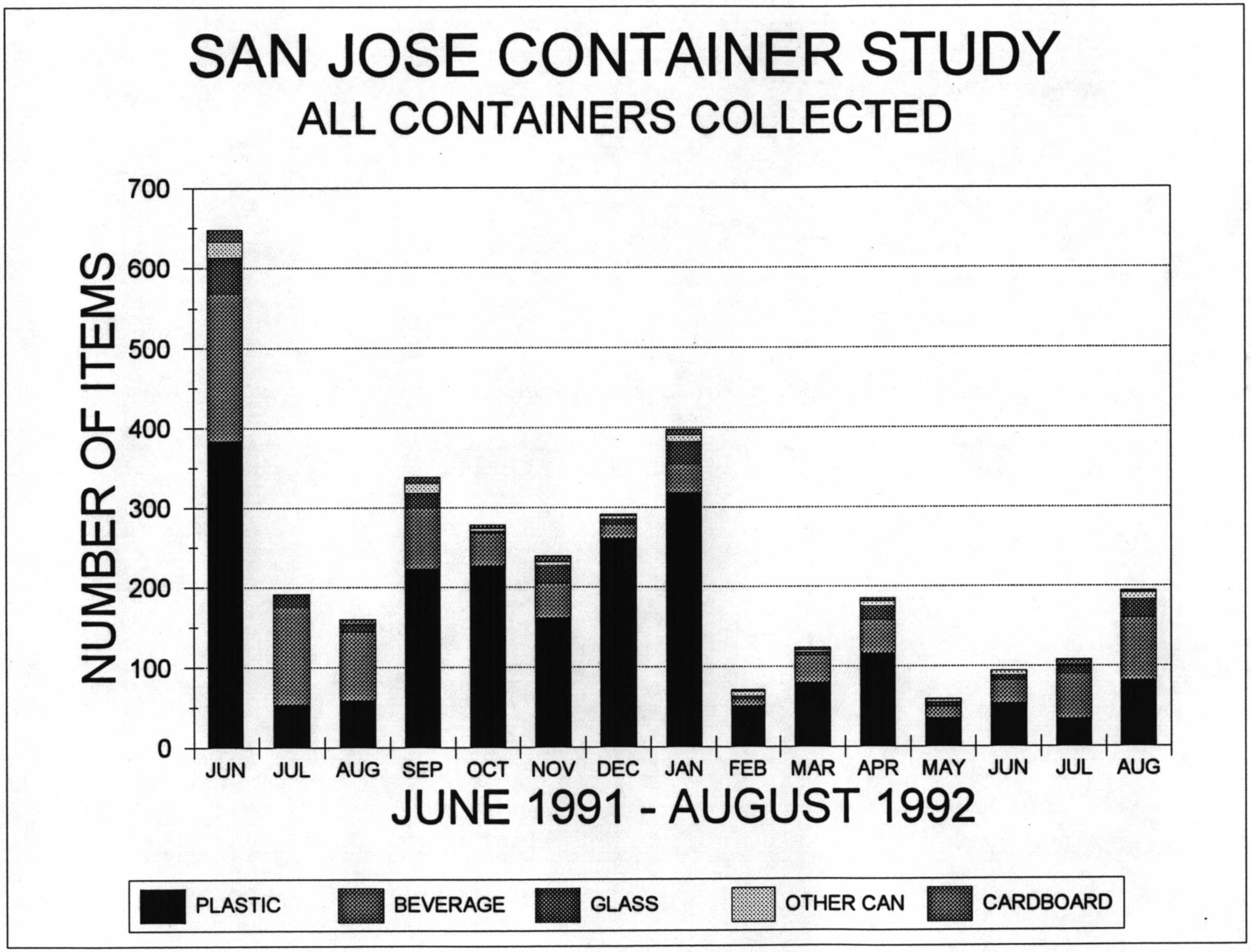


Figure 3.28. San Jose Container Study: Relative Proportions of Each Container Type for Each Month.

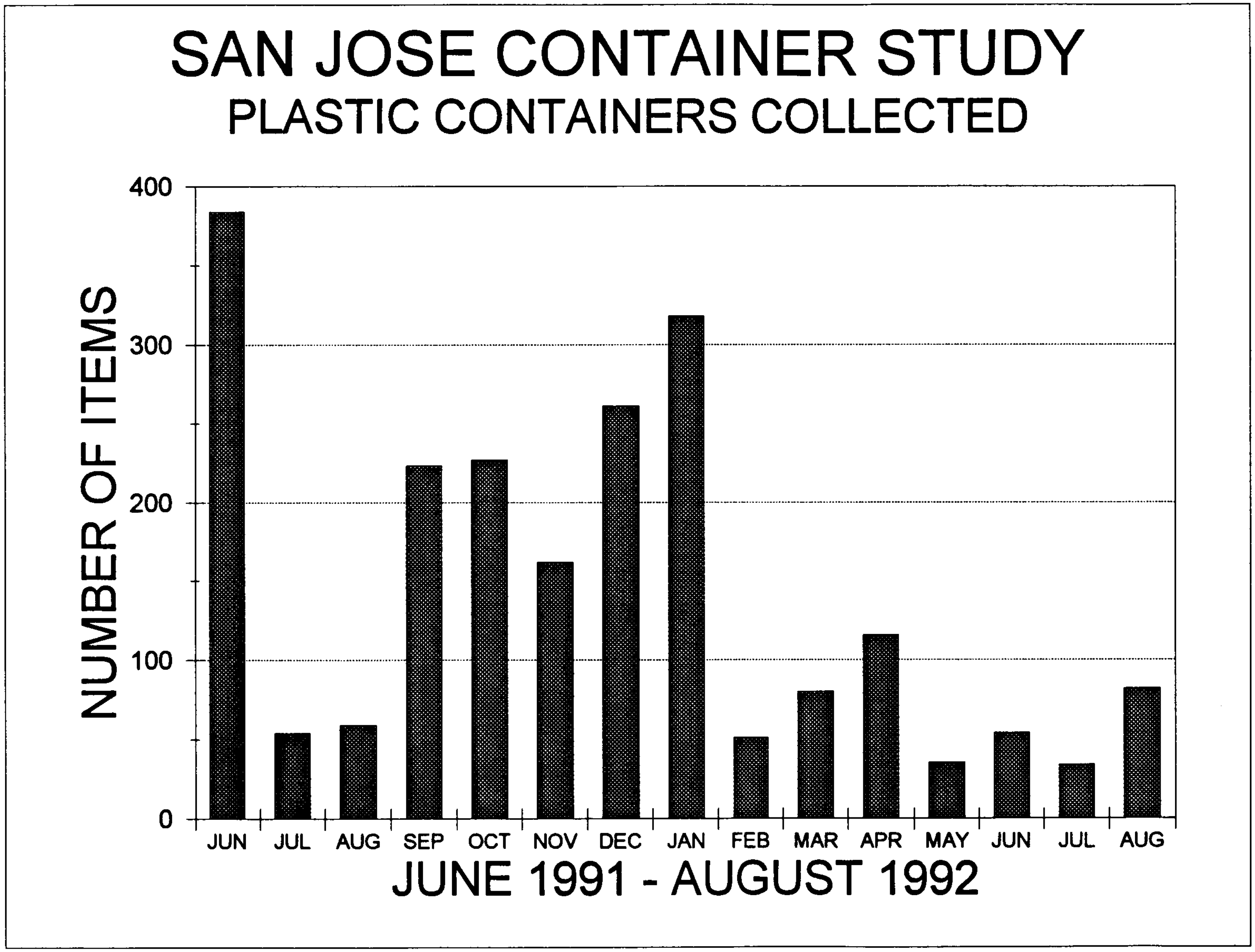


Figure 3.29. San Jose Container Study: Number of Items Collected - Plastic.

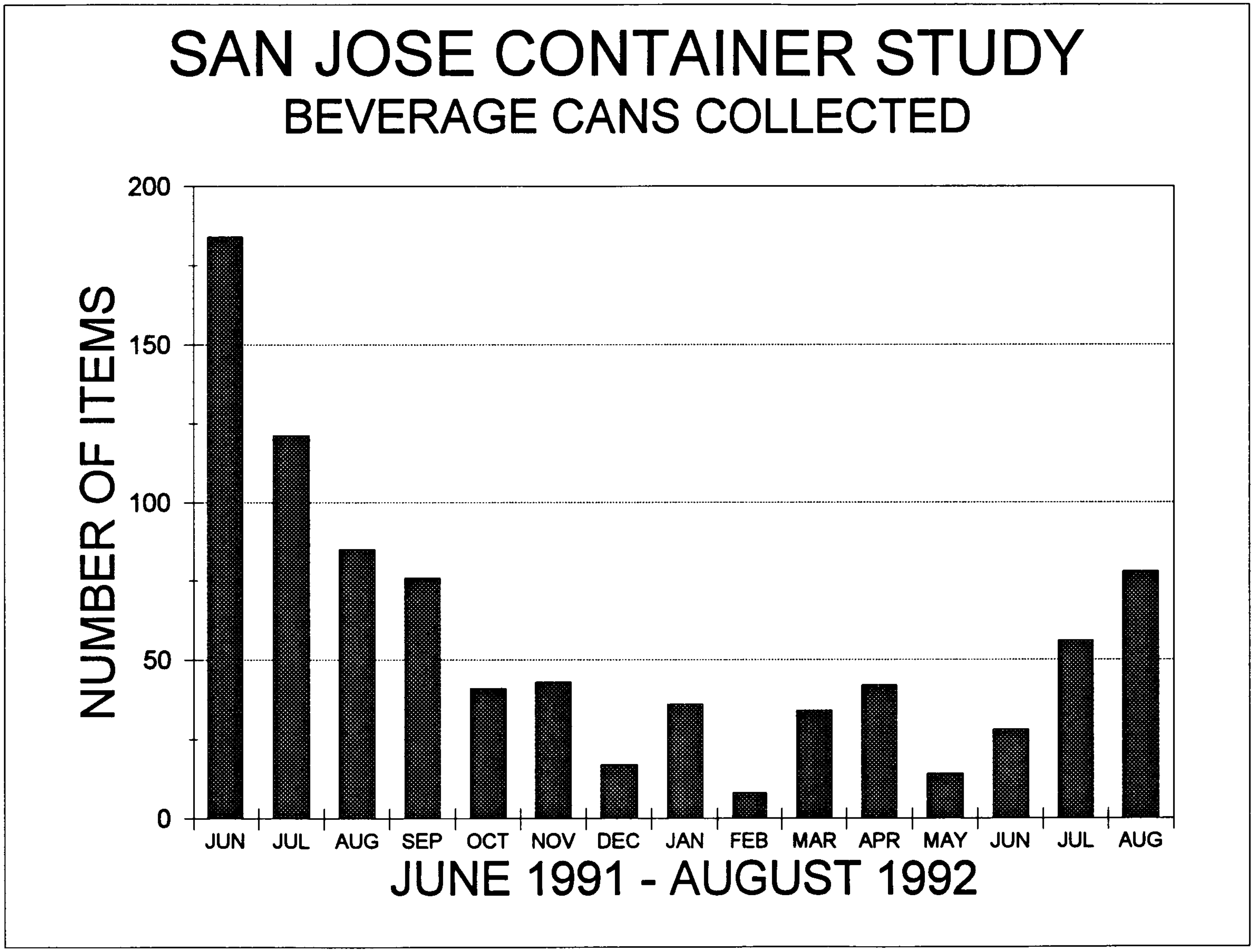


Figure 3.30. San Jose Container Study: Number of Items Collected - Beverage Cans.

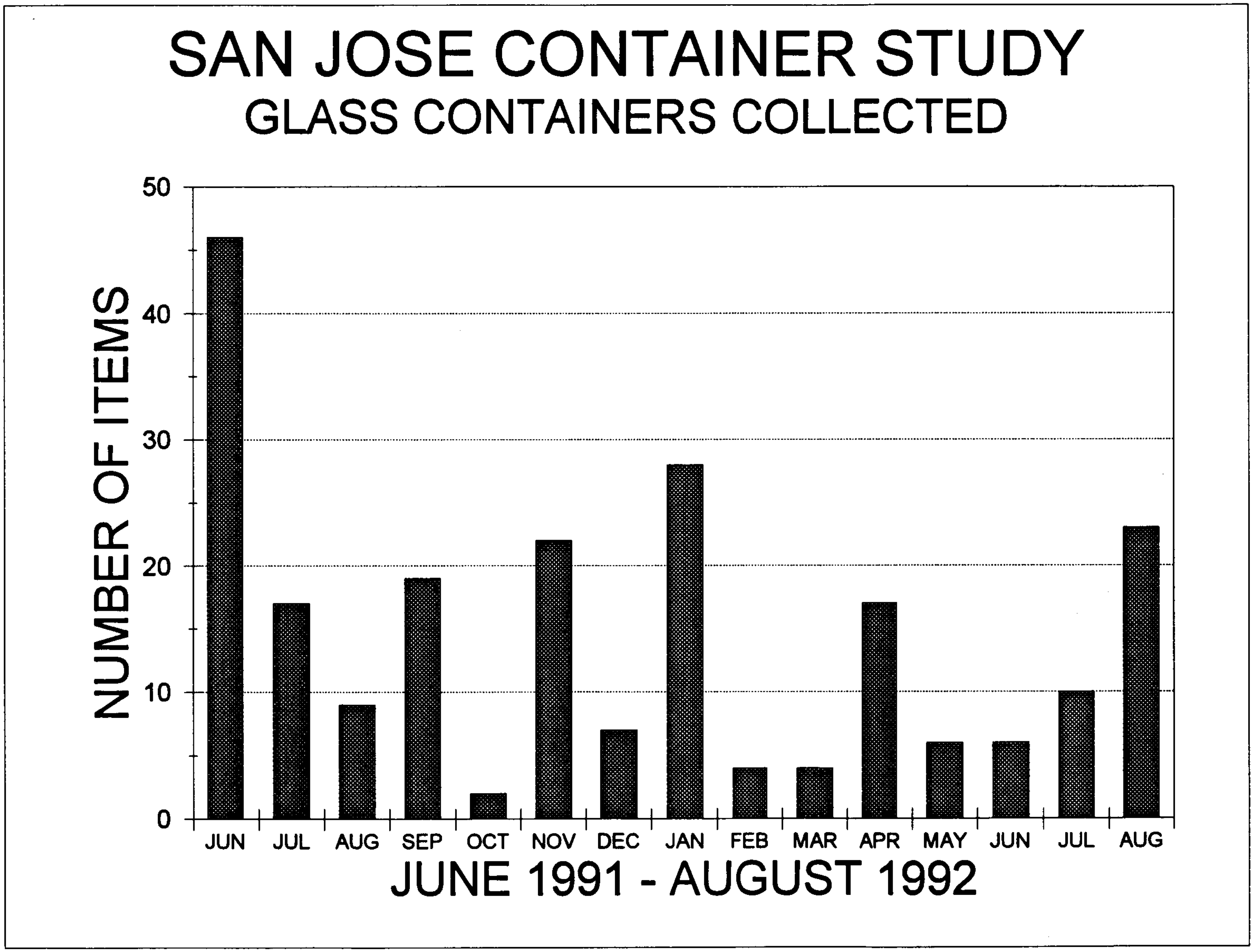


Figure 3.31. San Jose Container Study: Number of Items Collected - Glass.

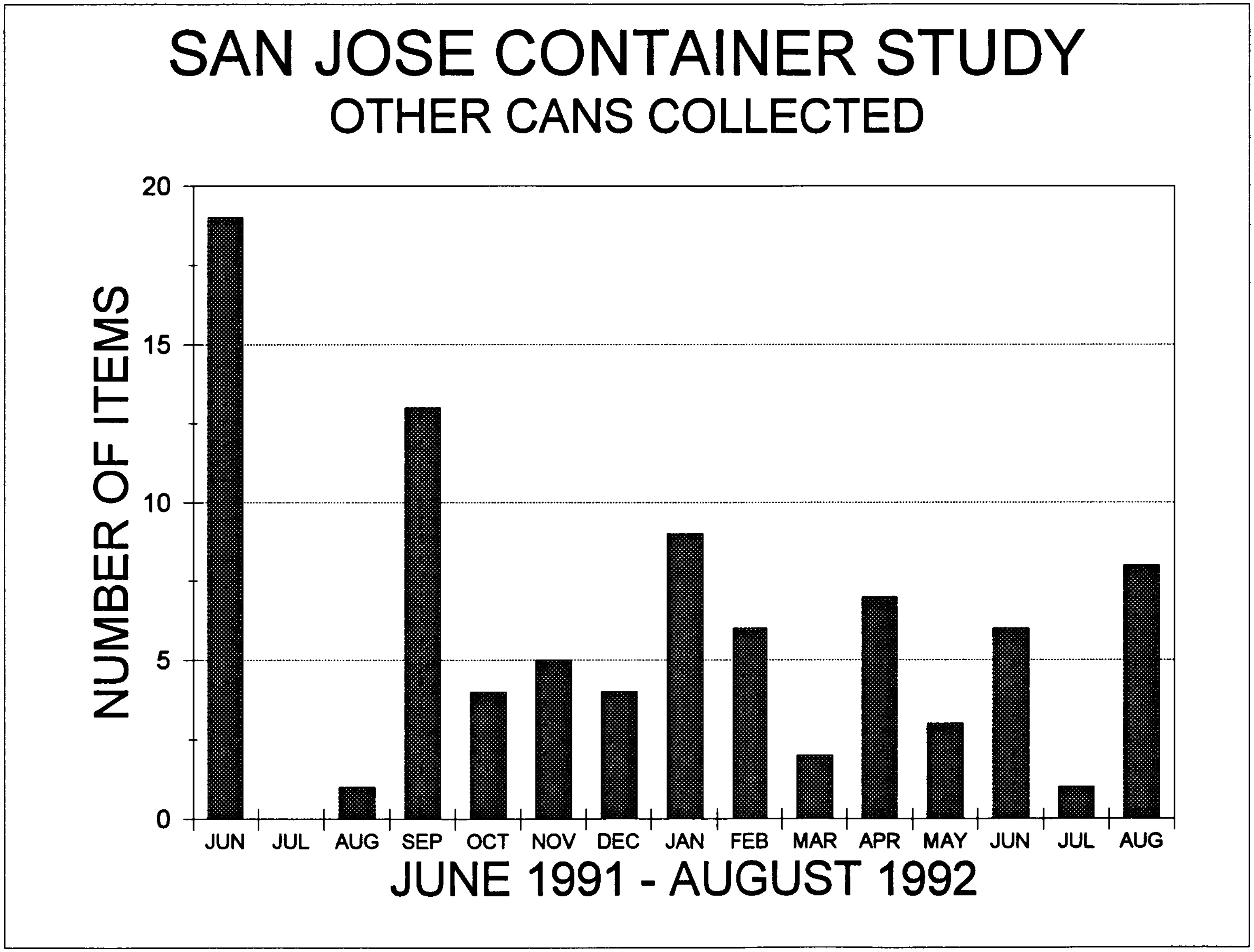


Figure 3.32. San Jose Container Study: Number of Items Collected - Other Cans.

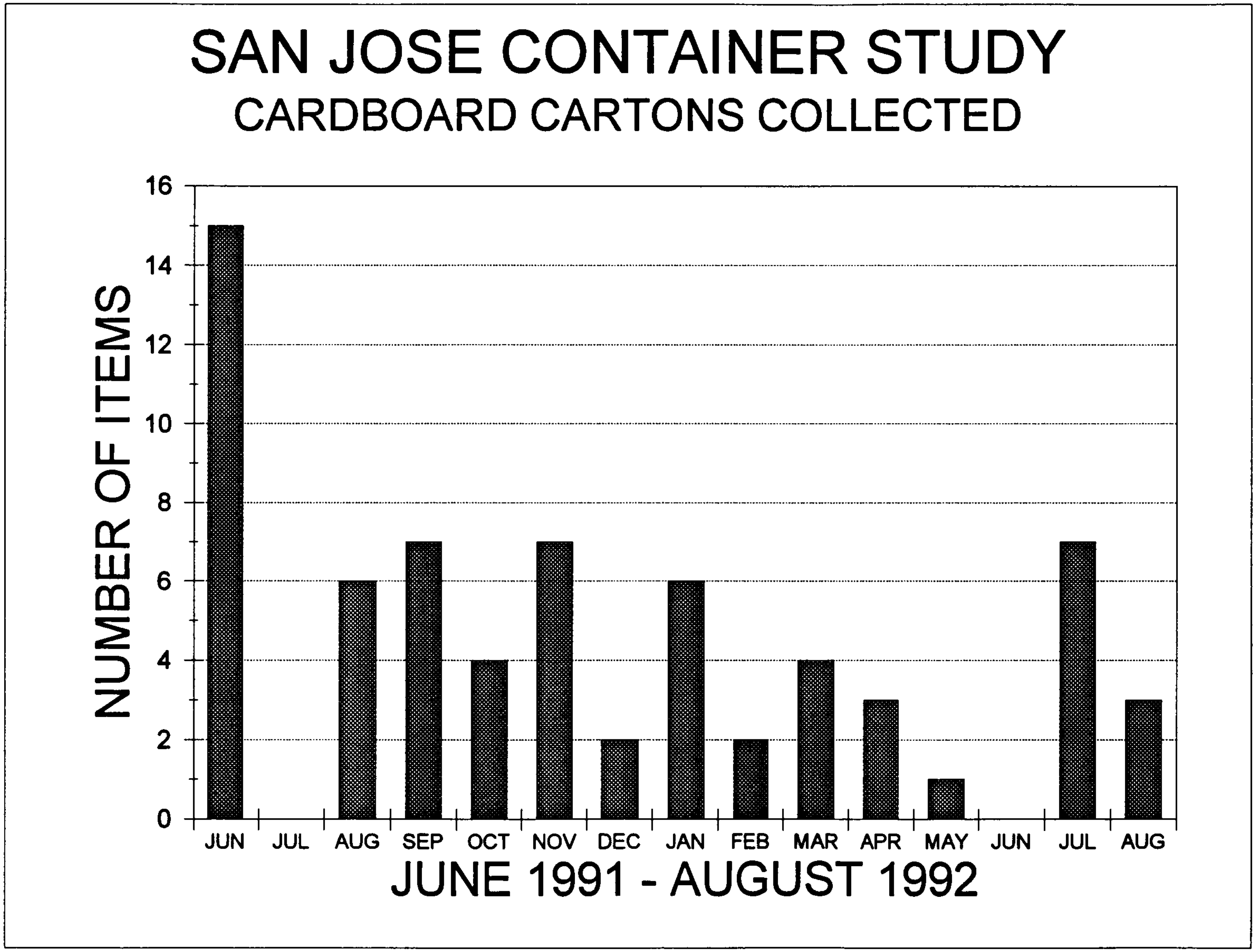


Figure 3.33. San Jose Container Study: Number of Items Collected - Cardboard Cartons.

Table 3.12: San Jose Island: Total and Percentage of Each Category for Each Collection

Month/Yr	Totals					Grand Total	Percentage of Total				
	Plas	Bevg	Glas	Ocan	Card		Plas	Bevg	Glas	Ocan	Card
Jun 91	384	184	46	19	15	**648**	59.3	28.4	7.1	2.9	2.3
Jul 91	54	121	17	0	0	**192**	28.1	63.0	8.9	0.0	0.0
Aug 91	59	85	9	1	6	**160**	36.9	53.1	5.6	0.6	3.8
Sep 91	223	76	19	13	7	**338**	66.0	22.5	5.6	3.8	2.1
Oct 91	227	41	2	4	4	**278**	81.7	14.7	0.7	1.4	1.4
Nov 91	162	43	22	5	7	**239**	67.8	18.0	9.2	2.1	2.9
Dec 91	261	17	7	4	2	**291**	89.7	5.8	2.4	1.4	0.7
Jan 92	318	36	28	9	6	**397**	80.1	9.1	7.1	2.3	1.5
Feb 92	51	8	4	6	2	**71**	71.8	11.3	5.6	8.5	2.8
Mar 92	80	34	4	2	4	**124**	64.5	27.4	3.2	1.6	3.2
Apr 92	116	42	17	7	3	**185**	62.7	22.7	9.2	3.8	1.6
May 92	35	14	6	3	1	**59**	59.3	23.7	10.2	5.1	1.7
Jun 92	54	28	6	6	0	**94**	57.4	29.8	6.4	6.4	0.0
Jul 92	34	56	9	3	2	**104**	32.7	53.8	8.7	2.9	1.9
Aug 92	82	78	23	3	7	**193**	42.5	40.4	11.9	1.6	3.6

the same level as found in June 1991. For the rest of 1992 until the study ended in August, accumulations remained low. Beverage cans (Figure 3.30) were numerous in the summer of 1991, but decreased steadily remaining low until the start of summer 1992. The last two months of the study, beverage cans increased again.

3.5.2 Sizes of Containers

3.5.2.1 Volumes

Containers on San Jose Island beach were found in a bewildering variety of volumes. The exception is the beverage can, nearly all of which come in one size, the standard American 12 oz. can. Volumes used were those stated on the label, stamped on the container itself, or in some cases, estimated. English units were converted into liters. To quantify the most numerous type of container, plastic, we classified them in three classes: larger than 3 liters, between one and three liters and less than one liter. Figure 3.34 is a bar diagram showing the three volume classes plotted by month. Bottles less than one liter dominate most months, but one-gallon milk jugs which account for most of the containers larger than 3 liters, are a significant volume of the total from September through December 1991 and March and April 1992. The total volume occupied by the plastic containers was $3.36m^3$ and by all other containers was $0.49m^3$.

3.5.2.2 Weights

Most assessments of litter on beaches, including the nation-wide volunteer beach cleanups, have compared the weight of material collected from one cleanup to the next (Figure 3.35). In this study we measured both the weight and volume of the containers. Table 3.13 compares the total weight and volume of containers collected by type.

Table 3.13: San Jose Island Container Study:
Comparison of Total Weight and Volume

Description	Weight(kg)	Volume(liter)
Plastic	239.39	3355.81
Beverage cans	49.21	306.68
Glass	68.13	96.29
Other cans	14.12	59.37
Cardboard	6.59	27.25
Total	377.75	3845.40

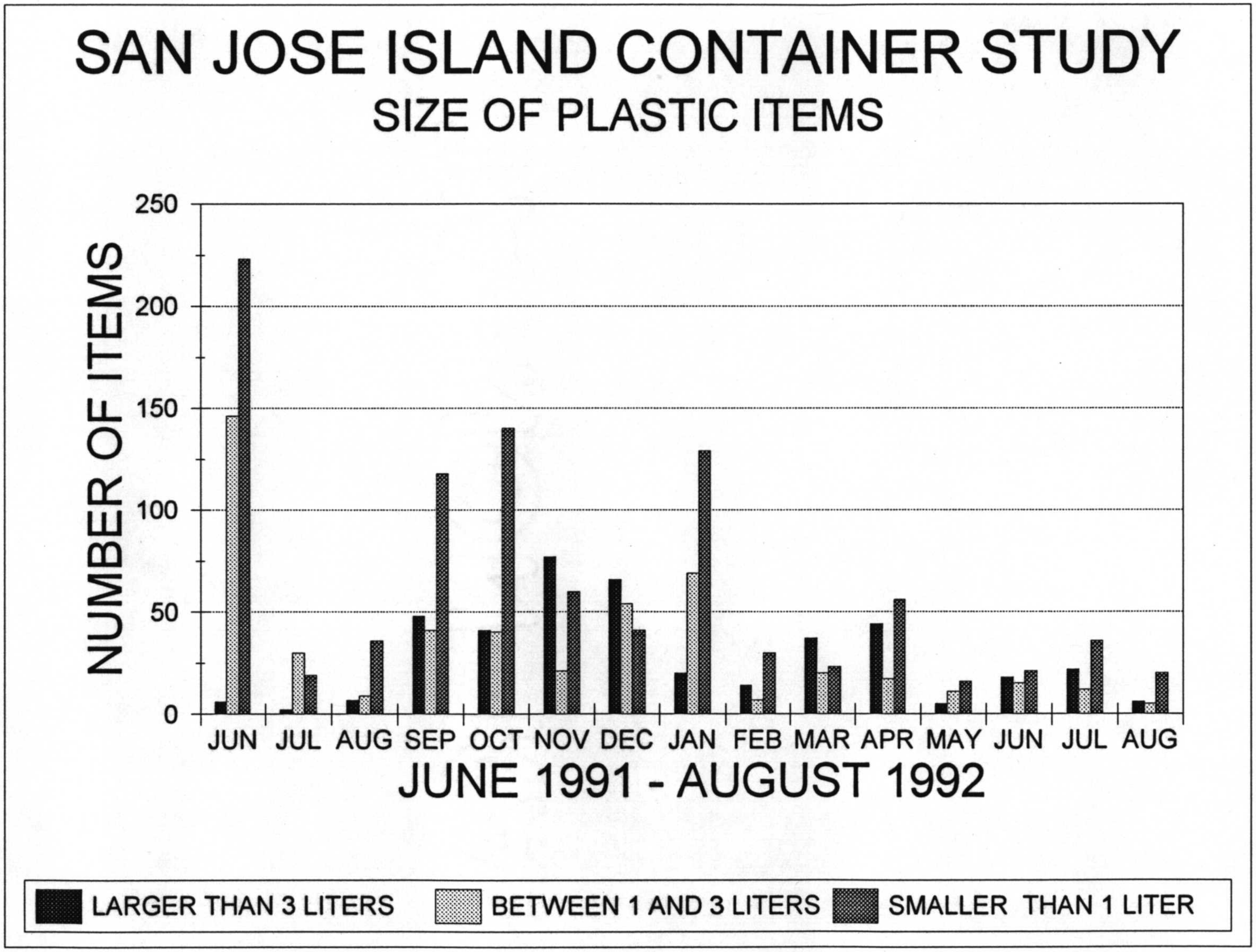


Figure 3.34. San Jose Container Study: Volume Classes Plotted by Month.

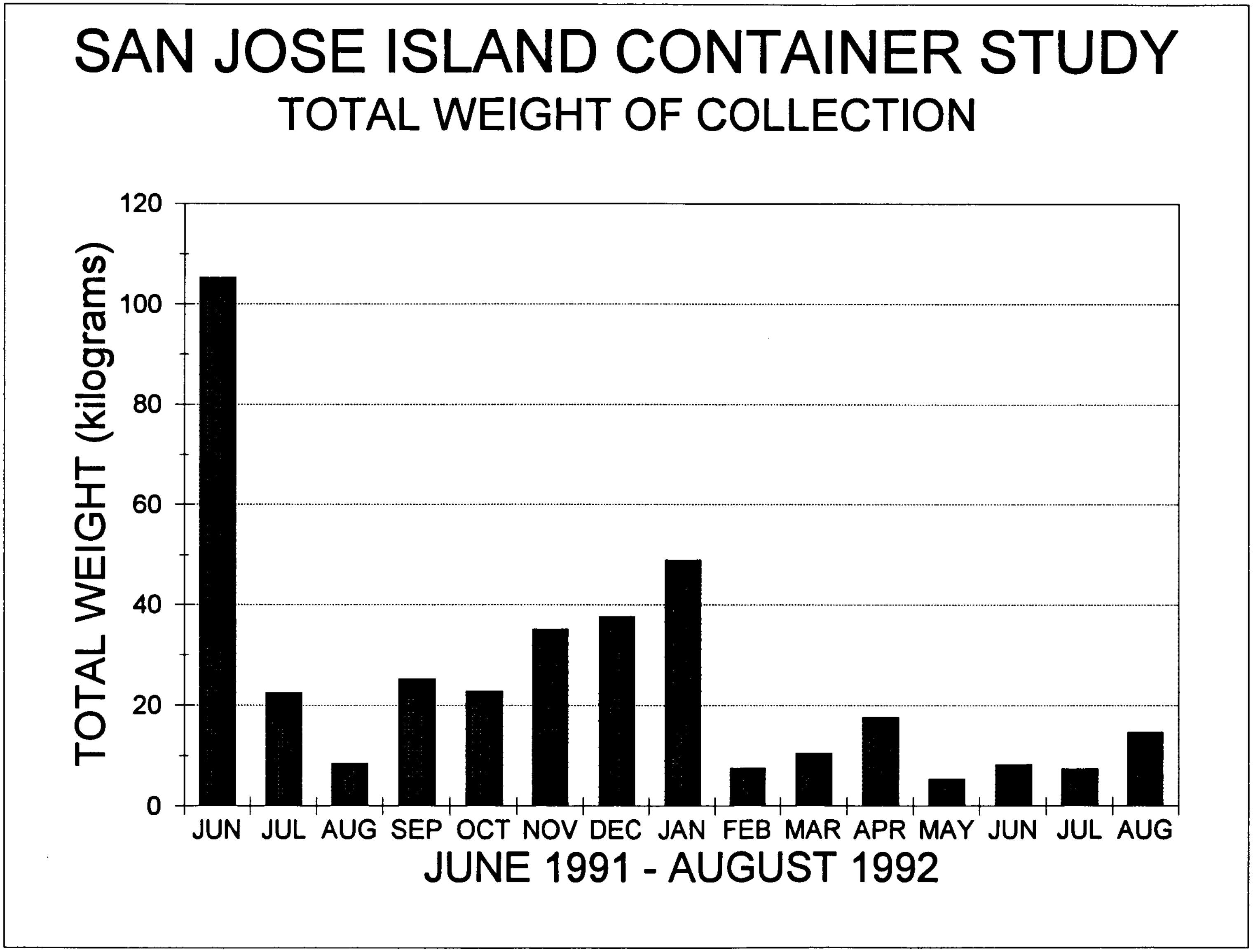


Figure 3.35. San Jose Container Study: Total Weight by Month.

3.5.3 Container Origins (by Country)

Products made and sold in the USA dominate in number the containers found on San Jose Island beach. Figures 3.36 through 3.40 show the breakdown by container type and "geographical" origin (USA, Mexico, foreign, unknown). Appendix H lists each container and its country of origin when identified. Over half of all the plastic containers (Figure 3.36) originate in the USA, but in some months, Mexican bottles equal or even exceed the US total. Except for June 1991, plastic bottles identified as foreign make up less than 20% of the total. The unknown (unidentified) category are probably of non-US origin. Beverage cans (Figure 3.37) are almost exclusively from the USA or imported and sold here. Far fewer glass, metal can and cardboard containers originated in Mexico so they were classified with the foreign material for the rest of the figures. The majority of glass containers (Figure 3.38) are of US origin but more than half of the other cans (food cans other than beverage, Figure 3.39) are foreign. Most of the cardboard containers are from the USA. (Figure 3.40).

3.5.4 The Turtle-Bite Problem

Many of the plastic and cardboard containers collected on San Jose Island had holes or cuts in them resulting from sea turtle bites. The author has long noticed this phenomenon on litter observed on Mustang Island and the present project afforded a chance to determine the magnitude of the problem. Nearly 60% of stranded loggerhead turtles examined (Plotkin and Amos, 1989) had plastic pieces in their gut. Figure 3.41 shows the number of plastic containers with turtle bites. Figure 3.42 expresses the data as a percentage of the total number of bottles. The mean for San Jose study was 12.5 bottles with bites or 8.7% of the total. It is believed that juvenile turtles during their pelagic stage feed on the windrows and patches of weed and litter and attempt to eat plastic either because it looks like a food item or has animals growing on it (Amos, in prep).

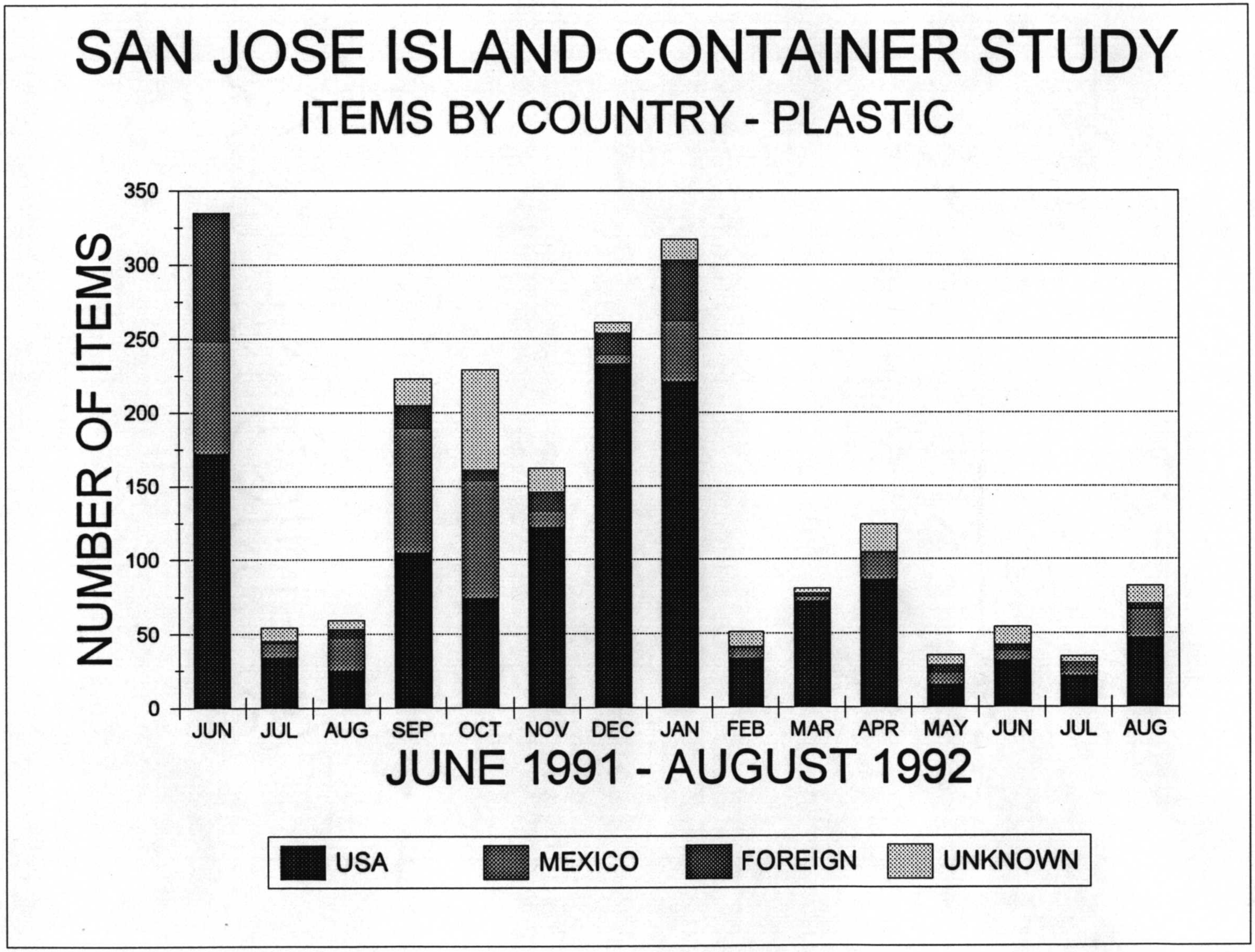


Figure 3.36. San Jose Container Study: Number of Items by Country - Plastic.

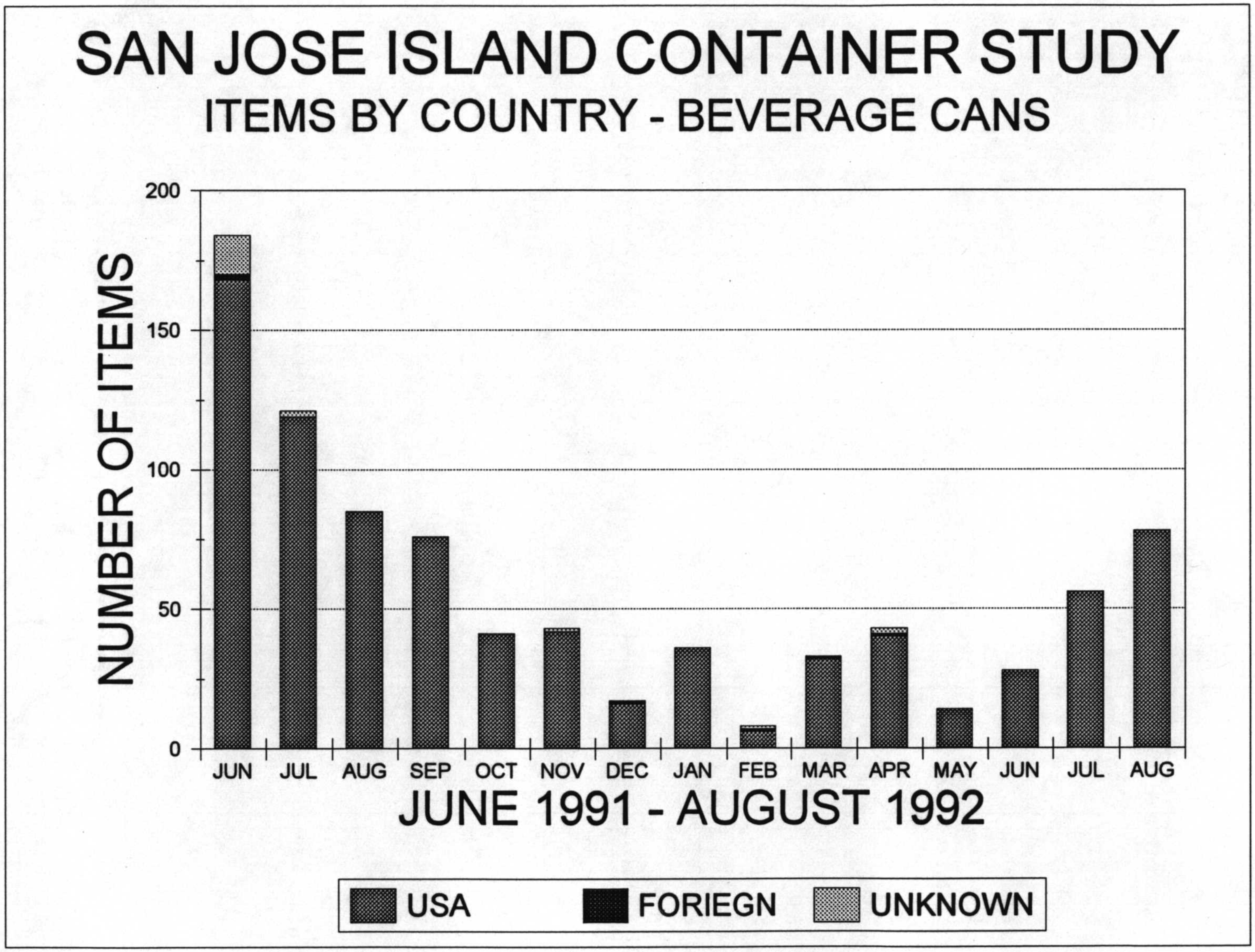


Figure 3.37. San Jose Container Study: Number of Items by Country - Beverage Cans.

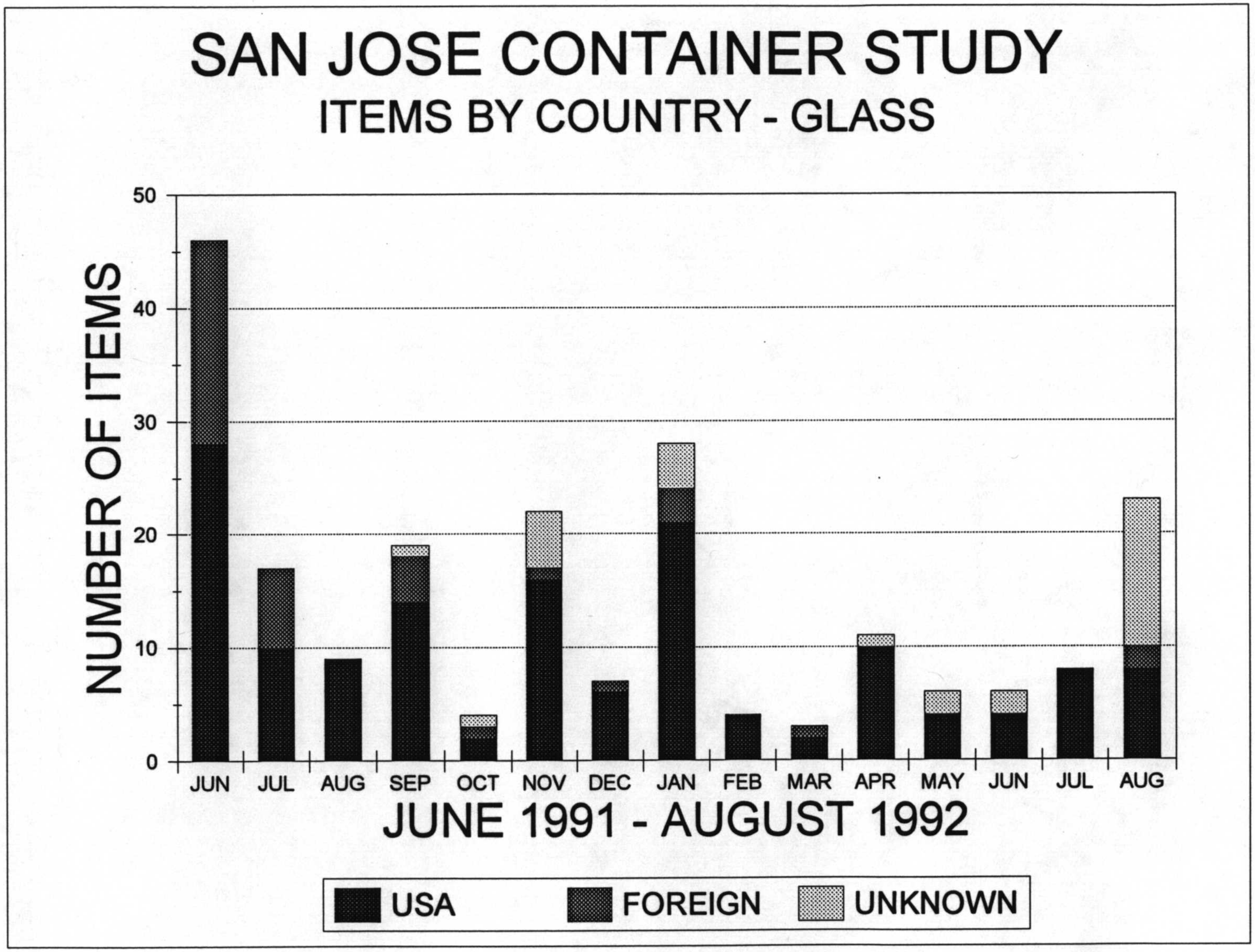


Figure 3.38. San Jose Container Study: Number of Items by Country - Glass.

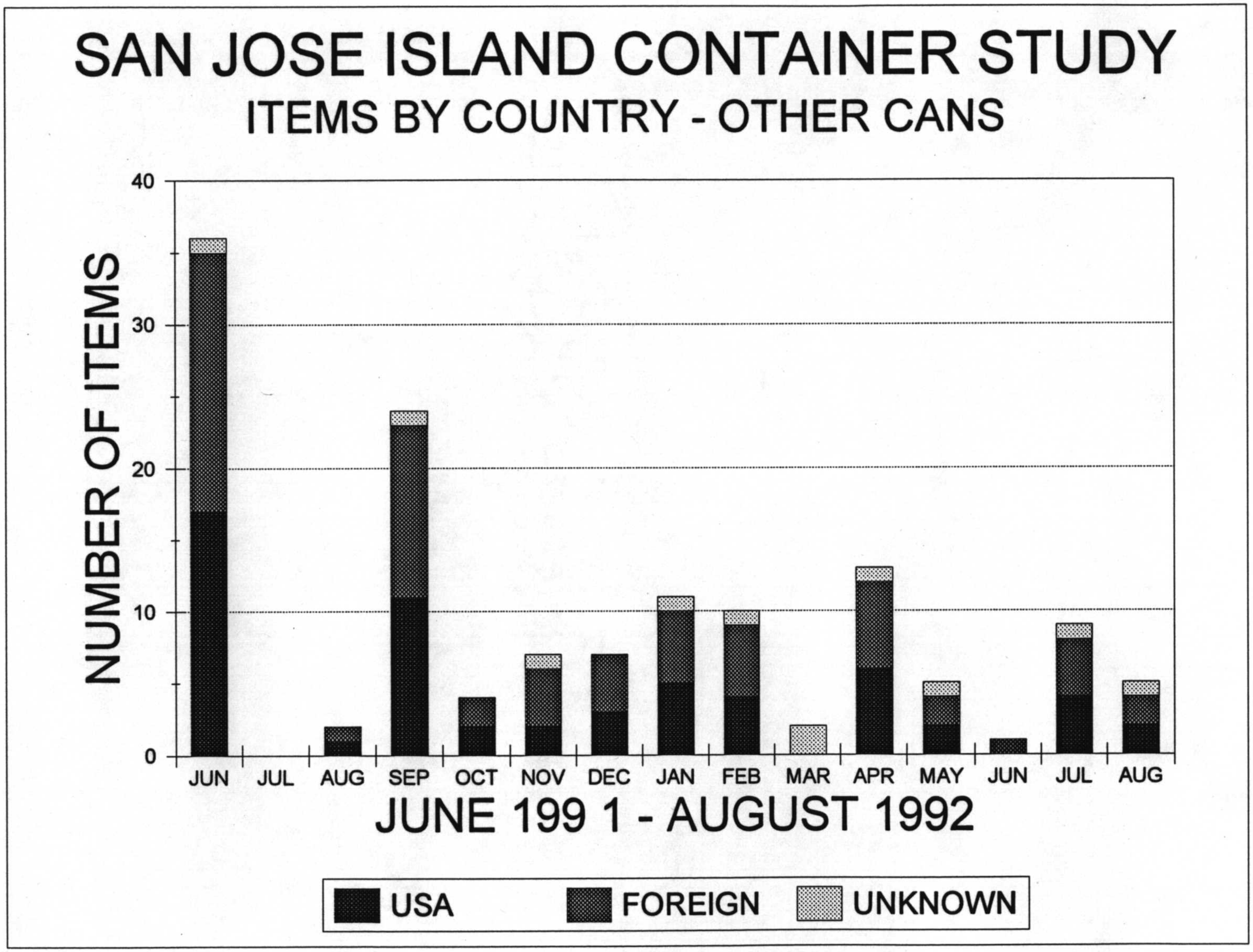


Figure 3.39. San Jose Container Study: Number of Items by Country - Other Cans.

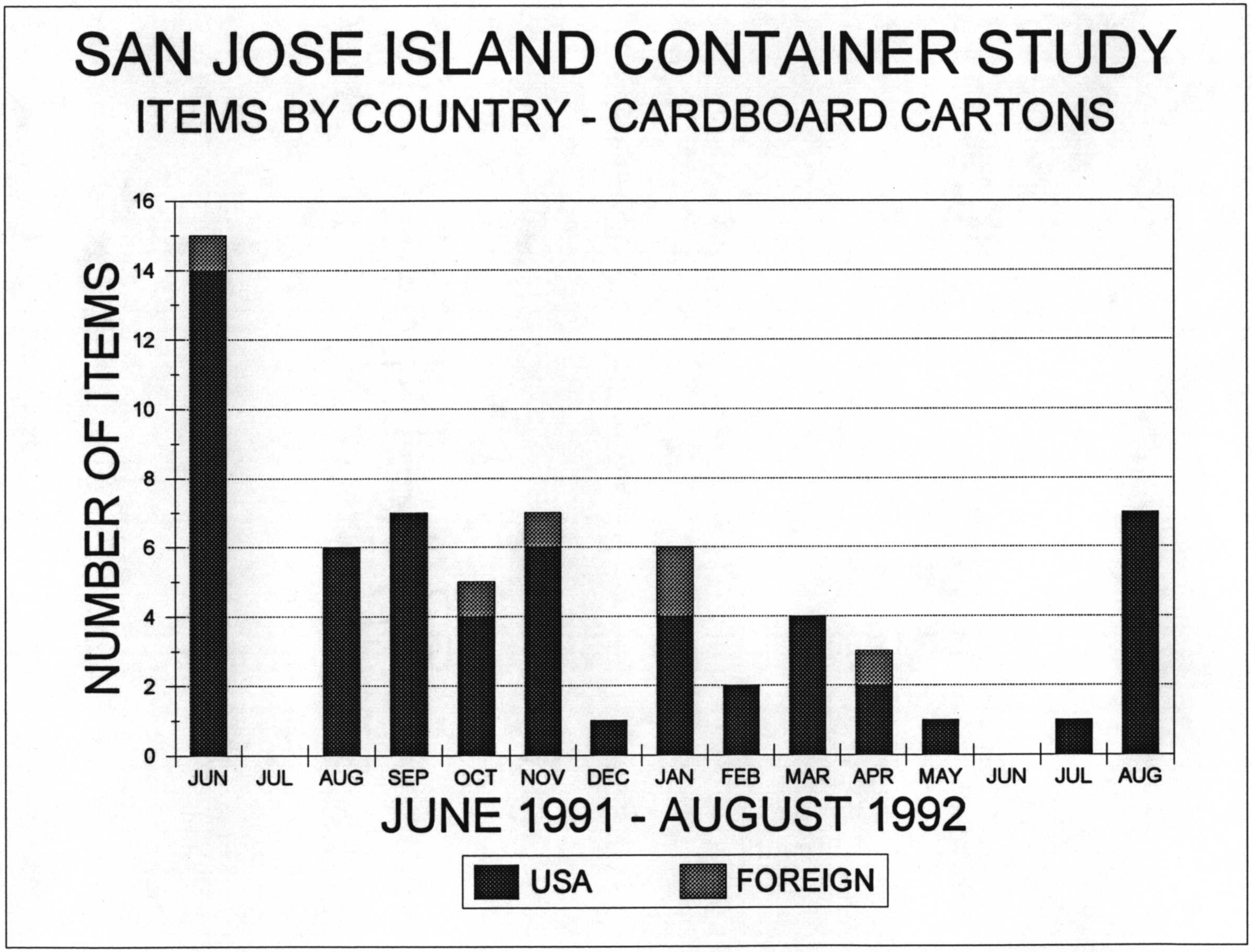


Figure 3.40. San Jose Container Study: Number of Items by Country - Cardboard Cartons.

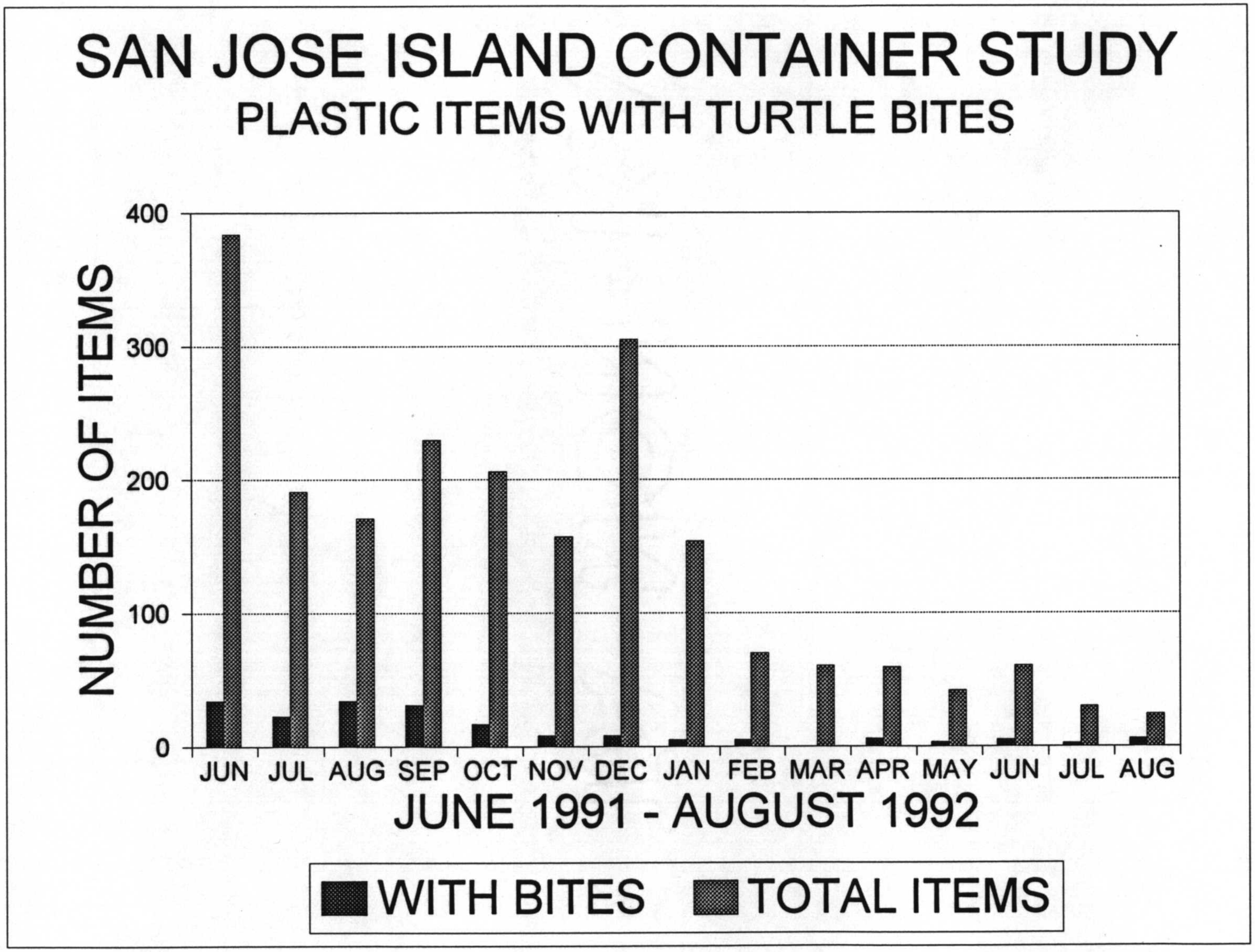


Figure 3.41. San Jose Container Study: Plastic Items with Turtle Bites.

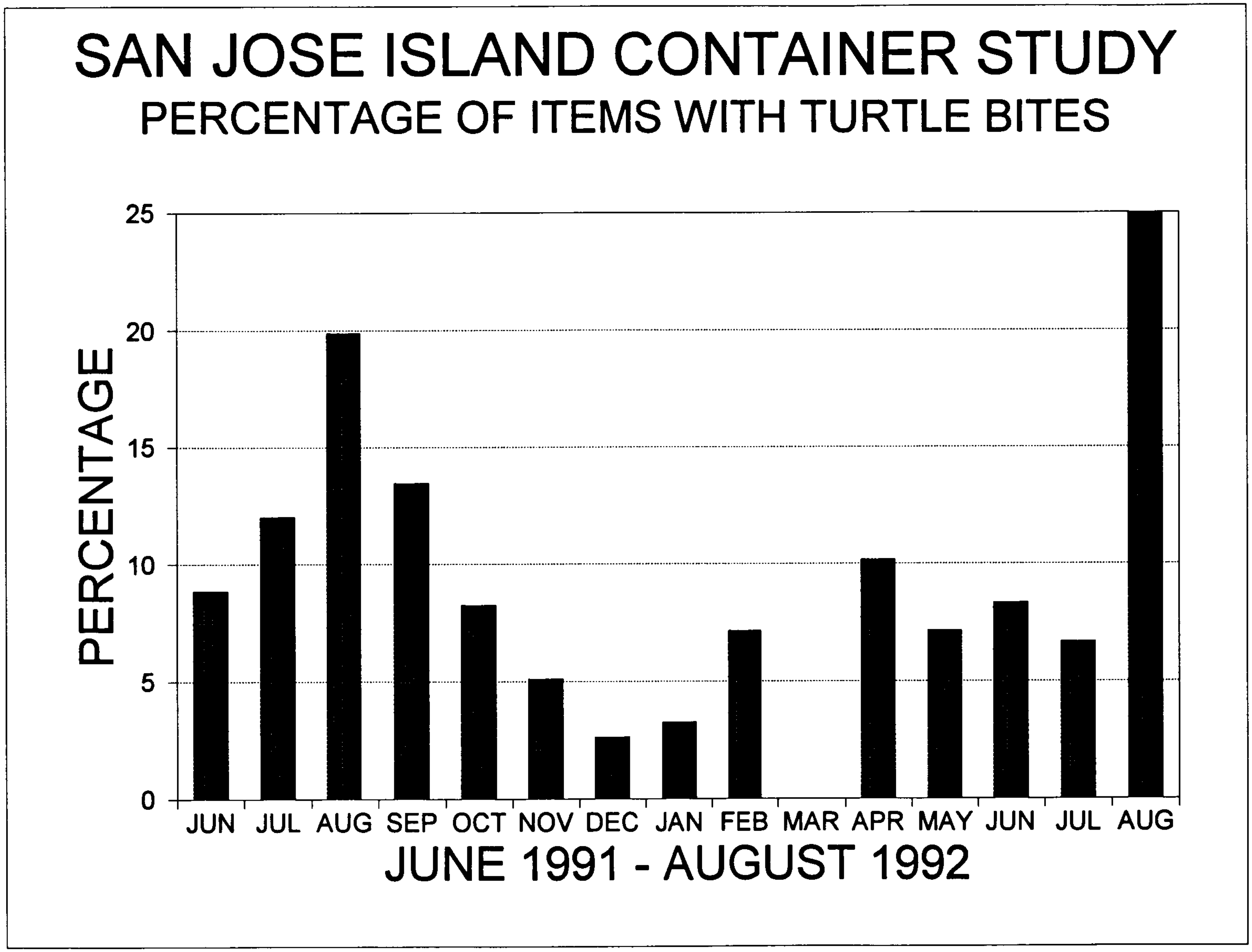


Figure 3.42. San Jose Container Study: Percentage of Items with Turtle Bites.

4. DISCUSSION

Annex V of MARPOL which prohibits the discarding of plastics at sea went into effect on 31 December 1988. Materials dumped at sea, including plastics, often find their way to beaches. Texas beaches in particular receive a heavy load of man-made debris due to their geographic location, the circulation patterns in the Gulf of Mexico and the volume of merchant marine, fishing, and recreational activities and the offshore oil industry in the gulf. Plastic and other litter on beaches have an adverse effect on tourism, pose a health threat to beachgoers, and cause serious problems with marine wildlife which can become entangled in or ingest the litter. It has been widely hoped that enactment of Annex V would reduce the litter on beaches. Therefore, a survey of a beach known to receive large quantities of debris from offshore, if done before and after the enactment of MARPOL Annex V, should indicate the degree of compliance with the law. In the follwing discussion I will briefly review survey methods, compare three other current surveys with the MMS-Beach survey, and make some observations on how future surveys might be conducted.

4.1 Beach Debris Survey Methods

Government agencies need to rely on beach debris surveys as one method of assessing the degree of compliance with or enforcement of MARPOL Annex V. A standard method of conducting beach debris surveys is needed if results from different locations done by different investigators are to be comparable. Dixon and Cooke, 1977 reported one of the first surveys to examine man-made items washed ashore on beaches. They began their surveys in 1973. Ribic *et al.* (1992), in their Marine Debris Survey Manual consider both shipboard and beach surveys. While both are applicable in the study of marine debris, for the present discussion, only the beach survey methods are considered. Amos (1993) compared four methods currently in use, including his own survey techniques. I will summarise the results of those comparisons here with reference to the Gulf of Mexico and specifically, Texas. Some of the following has been paraphrased or excerpted from Amos (1993).

4.1.1 Objectives

Ribic *et al.* (1992) state that "different survey designs are necessary to address two objectives", baseline and trend-assessment. I list five possible objectives for doing beach-debris surveys;

1 **Trend assessment:** Is the quantity of marine debris on beaches decreasing or increasing?

2 **Identification of sources:** Who is responsible for the debris on the beach?

3 **Environmental conditions controlling marine debris on beaches:** What controls the beaching of marine debris?

4 **Assess the effect of marine debris on a beach:** Does the debris present a threat to human visitors, a detriment to the economy of a community?

5 **Effect of marine debris on wildlife:** How detrimental is marine debris to animals whose habitat includes nearshore waters and beaches?

Although I believe all these objectives should be considered in any comprehensive study, it is objectives one and two I will discuss here.

4.1.2 The Ideal Survey Conditions

Let us assume that for trend assessment, the basic survey method is to remove all debris from a given beach transect for examination later. For perfect results, all material would be removed by the surveyors and only the surveyors, and all new material beached after one survey remained there until the next. Errors would be limited to counting accuracy and the ability to identify materials. Pilot surveys could then be done to determine the optimum surveying interval and distance to survey. As Ribic *et al.* (1992) point out, a suitable statistical scheme should be decided to aid in analyzing the data. It would not matter where the debris originated if the objective of the survey was solely to establish a baseline and subsequently to investigate trends. For source association, however, the ideal would be that indicator items unique to each offshore source could be clearly identified as such. The counting method used as part of the present MMS Beach survey also has the same ideals, including removal following each survey. The removal does not have to be done by the surveyors. Counting and identification skills play a larger role in the accuracy of the results. Unfortunately, such ideal conditions do not occur.

4.1.3 The Real World

In the real world, several peculiarities of the distribution of beached debris make accurate surveys most difficult to obtain. I list some below.

1 **Longitudinal and latitudinal debris distribution:** debris is distributed non-linearly both along the shoreline and across the beach width at any instant in time. Temporally, it is beached at frequencies ranging from tidal to daily, weekly, seasonally, and inter-annually.

2 **Debris dispersal and concentration:** Once on the beach, debris is dispersed by winds and tides, or concentrated by accumulation at dune lines. The same items may be repeatedly dispersed and re-beached.

3 **Debris burial:** Burial of debris takes place in the foreshore, swash zone, backbeach, and dunes. Burial and exposure may be frequent occurrences.

4 **Debris removal:** Many municipalities, resort beaches and counties have beach-

cleaning programs. These often sporadic efforts greatly effect results of beach debris surveys on such beaches.

5 **Debris sources:** All beach debris does not come from offshore. Yet many items are used by beach users, offshore industries, and land-based sources. Separating these is one of the most difficult aspects of beach debris studies.

4.1.4 Choosing a Beach

From the above it would seem that some of the variables could be eliminated by using a remote, uncleaned beach to survey.

The following criteria must be considered in selecting a remote survey beach:

1--Availability of a 4-Wheel Drive or all-terrain vehicle.
2--Proximity of a building for a counting/staging area.
3--Availability of a boat or other conveyance to get to the beach.
4--Proximity of headquarters of surveying group.
5--Availability of a place to dispose of the collected material.

Using Texas as an example, I find just eleven suitable beaches covering just 50 of the 350 miles of Gulf coastline. Not all of these are ideal. The beaches are described in detail in Amos (1993).

4.2 Comparison of Four Beach Debris Surveys

To examine the options used in completed or on-going surveys for beach debris, I summarize the suitability of four recent efforts, including the MMS Beach surveys (Table 4.1).

4.2.1 Island Beach State Park

This survey is being done monthly by volunteers from the Alliance for a Living Ocean (ALO). The Center for Marine Conservation (CMC) organized this survey and analyzes the data under a grant from EPA. The survey is based on a statistical design (Ribic, 1990) and is conducted on the Island Beach State Park facing the Atlantic Ocean. The section of the beach used for the survey has greatly restricted use under Park regulations and is not cleaned.

At 28-day intervals, a 500 meter transect is surveyed by collecting all debris found there. Two adjacent 500-m transects were examined for littoral drifted items but this scheme was later abandoned. Starting in May 1991, 26 surveys have now been completed (E. Gotshall, pers. comm.), of which 23 are analyzed. The mean weight in $kg.km^{-1}$ of all items per survey ($n=23$) is 16.6 (7.0); maximum, 54 (21.8); minimum, 4.6 (1.4); Standard Deviation, 8.29 (3.49). Numbers in parenthesis are quantities of all plastics. Compare this with the San Jose Island values ($n=15$) of mean, 100.6 (63.8); maximum, 420.8 (252.4); minimum, 21.3 (11.4); SD, 99.3 (66.1).

Table 4.1: **Beach Debris Survey Examples** (modified from Amos, 1993)

	location	**objectives**	**dist (km)**	**freq**
1	Island Beach, NJ	trends, littoral drift	1.50	Monthly
2	Padre Island National Seashore, TX	trends, target sources littoral drift	0.05 (4 sites)	Daily
3	Mustang Island, TX	clean beaches,	up to 3.75	
	San Jose Island, TX (Coastal Cleanup)	trends, education	1.00	2/Year
4	Mustang Island, TX	trends, sources	11.80	Weekly
	Mustang Island, TX	micro debris	0.01 (3 sites)	Weekly
	Mustang Island, TX	sources,trends	11.80	Alternate days
	San Jose Island, TX	sources	0.25	Monthly

Note the large differences in the transect distances used in these surveys.

The mean weight of plastic on the Texas beach is about an order of magnitude greater than that on the New Jersey beach. Because of this, and because the method requires volunteer workers, I conclude that this survey method would not be suitable for use in Texas. The work would be particularly arduous if the littoral drift study was included in a Texas survey, as it was when I observed the New Jersey effort in 1991.

4.2.2 Padre Island National Seashore

The National Park system has had a Marine Debris Monitoring Program since 1988 (Cole *et al.*, 1990). Surveys are conducted at eight National Parks and Seashores on all U.S. coasts. Surveys are conducted quarterly. The Padre Island National Seashore in Texas is recognized in this program to be a special case due to the volume of materials beached there. While PAIS still does the quarterly surveys they have embarked on an ambitious daily survey that is now nearing its one-year completion date. It is this survey I will summarize here.

Four 50-m transects of beach are surveyed daily, two within the Closed Beach, and two outside in an area where automobiles are permitted but where the beach is not cleaned. Doing the survey daily was a revelation to the PINS group (J. Miller, pers. comm.). They soon discovered that the quantity of the 'resource' was highly variable within this sampling period. The team made careful efforts to quantify littoral drift and burial of man-made debris, especially near the dunes. As a result of this, they now feel that the returns from looking at the debris which is in the main dunes produces limited results of questionable value to their overall goals.

More in keeping with their objectives was the discovery that debris positively identifiable with the shrimping industry not surprisingly came ashore when the Gulf shrimpboats were working nearshore (i.e. their boats were visible from the beach). At first volunteers were used but now they use only PAIS personnel to carry out the program. Such intensive surveys require a large operating budget.

4.2.3 Mustang/San Jose Islands (CMC)

The most extensive of all the beach debris surveys and cleanups is the International Coastal Cleanup organized by CMC. Now in its sixth year, the data base is huge, with thousands of entries from data cards filled out by volunteers entering up to 81 categories of debris items (CMC, 1992). CMC does not claim that their survey design is based on rigorus statistical foundation (O'Hara, 1990), but the data base is large enough that it needs to be scrutinized to determine if reliable trends can be realized. Some independent analysis has been done on specific beaches cleaned by volunteers (Lindstedt, 1991). I have done several comparisons of debris on the beach immediately before and after the cleanups on Mustang Island and one detailed analysis of items recorded versus what was actually collected on San Jose Island (Amos, 1993). Can the CMC data with its thousands of volunteers and large coverage of the Nation's beaches be used as a measure of trends and or identification of debris sources? Did the volunteers get everything off the beach and are the data cards accurate when compared to what was actually collected?

Volunteers did a good job in removing large items of litter from the beach. They were less successful in removing fragments of styrofoam and plastic pieces. Sections of the beach were missed entirely because it is not possible to assign volunteer groups to the entire beach, especially the more remote ones. In recording items, the volunteers were again quite accurate with large, easily identifiable objects. However, some errors were surprisingly large for familiar items (esp. beverage cans). They fared less well on both counting and identifying smaller, more nebulous items. In the result of the one experiment, the overall error was 50% undercounting. There were errors in recording how many collection bags were filled. Of the 127 bags we collected for analysis, 111 were listed on the data sheets. Widely-published headlines, e.g. "1400 Tons of Trash Collected from Nation's Beaches" are based on the bag count and a mean recorded on the cards and an estimated mean weight per bag. Our experiment gave a mean weight of 13.5 lb per bag (n=127, SD=17.2). Eleven percent of this weight was due to sand, not counting that difficult to remove from bottles and cans. An additional weight, equivalent to 3.1 lb per bag, was accounted for by large, unbagged items. Using numbers from CMC, (1992) and our mean bag weight, we calculate that there were 10.9 bags per data card turned in to CMC. This is twice the number obtained in our experiment (5.8 bags/card).

The above is the result of only one experiment and is not meant to detract from the immense utility and public service that the International Cleanup provides. Some of the trends in the CMC data mirror those found in the MMS beach study presented here. If the CMC Cleanups are to be used for trend assessment and source identification then more control experiments like the one done by Amos (1993) should be done at spot locations around the country by trained observers. The CMC data base may be compared to another, once maligned data set collected by volunteers, the Audubon Christmas Bird Count (Drennan, 1981). Trends in bird populations are being analyzed using the CBC data.

4.2.4 Mustang/San Jose Islands (MMS)

The four kinds of surveys have been described in detail in the present report. An important finding from the counts is that the quantity of debris beached varies by several standard deviations from the mean, as a function of both time and location along the beach transect. Advantages of debris counting over collecting are; 1) a much longer transect can be used; 2) debris data can be entered directly into a computer on-site; 3) longitudinal debris distribution can be mapped in real time; 4) A single observer can conduct the surveys; 5) a count could include only easily recognizable and countable target items thus reducing the time and effort required. Disadvantages using this method are; 1) items may be re-counted in subsequent surveys (not a disadvantage if the objective is to quantify the debris standing stock); 2) a certain skill and consistency in counting technique is required; 3) items may be missed if the swath counted is wide or if they are obscured by natural debris. A long-term project like the MMS beach survey may be compromised if the beach usage and cleaning efforts change during the course of the survey. The difference between the San Jose Island container study and other debris collection surveys is that only certain items were collected. While this made the field work easier, the work back at the laboratory was more detailed. Every item was examined, classified, weighed, and described in detail as the focus of the study was to identify sources.

If materials discarded at sea by vessels under MARPOL's regulations were the only litter found on the beach, then it might be said that any reduction noted was due to compliance with Annex V. Unfortunately Mustang and San Jose Island beaches receive additional litter from beachgoers and from the rivers, bays and estuaries (although some of these waterways also come under the MARPOL regulations). Mustang Island beaches are cleaned by local authorities making assessment of debris and litter input difficult. Part of the study beach has been cleaned more vigorously recently but the effort is still seasonal and unpredictable. Litter washed ashore is also subject to redistribution by storms, winds, high tides and sand burial. Despite these variables, the study has shown some significant changes in the quantity of litter on the study beach since MARPOL went in to effect. Several of the most commonly found types of litter have been declining since 1989.

The lesson from the above surveys is that trying to assess "everything" which is stranded on a beach requires immense effort, fortitude and time, especially with limited personnel to do the assessing.

4.3 Future Beach Debris Surveys

Drawing on the lessons learned from the present study and other beach debris surveys, I list here some criteria for future surveys to study beach debris. For trend assessment and source identification, surveys must be done frequently, on a remote beach, cover a length of beach sufficient to avoid extrapolation errors, use trained personnel, and perhaps target only a few indicator items. The study period should cover at least one year and preferrably longer.

Duration:	Multi-year, or one-year for source identification.
Frequency:	Weekly or less (monthly for source identification on remote beach).
Length:	At least 1-kilometer.
Width:	Limit to area between shoreline and high tide line.
# Surveys:	In Texas, three or four to cover the coastline and the current regimes.
Location:	Remote, uncleaned beach with access by boat and availability of vehicle on-site. Remote, uncleaned beach with access by 4-wheel drive vehicle. Selected beach with easy access, could be cleaned but need cooperation of beach personnel. Proximity of research or marine regulatory agency facility.
Basic methods:	Use trained personnel. Collect debris and clear site after each survey. Select target items to avoid logging every piece of plastic. Counts of target items okay for longer transects. Use controls and estimate errors. Collect ancilliary environmental data.
Special surveys:	Surveys of longer beach transects using existing beach-cleaning personnel (they should be trained) to collect and researchers to examine. Surveys which target specific items or sources.
Ancilliary data:	Reliable data on quantities and types of supplies that the various maritime industries use at sea. Canvass industry and professional organizations. Port, shipping and fishing industry statistics. Weather and oceanographic data.

5. CONCLUSIONS

The number of people visiting the beach has increased as has the attendant activity and potential for litter input. Beverage cans, the most common of beachgoer litter on the beach, have remained steady; but plastic six-pack rings, cups and lids and cloth have all decreased. Paper products, balloons and toys have increased. Two items of natural debris (*Sargassum* weed and driftwood), important because of their association with floating litter at sea, have increased. Tarballs have decreased and this trend has been of sufficient magnitude to have been noticed by the public at large. Of the items associated with the fishing industry (mainly shrimping in the study area), several have declined including milk jugs and egg cartons, typical shrimp-boat galley waste. In contrast Mexican bleach bottles and produce sacks have increased. Items associated with the offshore oil industry have decreased: in the case of the large plastic sheeting and write-protect rings, dramatically so. The 5-gallon plastic pail with labels showing various chemicals used by the offshore industry has also declined significantly. Items from the maritime commerce business are more difficult to identify but typically are galley-waste peculiar to that industry with many bearing foreign labels. The one-liter cardboard milk carton, sold almost exclusively by ship's chandlers, has declined. Galley waste, in general, has declined with the exception of plastic bottles. The source of such bottles is not exclusively galley waste. The origins of the most numerous forms of litter on the beach, styrofoam pieces, plastic bags, and miscellaneous plastic pieces are not known and are probably from multiple sources. Styrofoam and plastic bags have noticeably declined while the miscellaneous material has increased. When assessed by weight rather than count, both styrofoam and (miscellaneous) plastic show declines. The overall conclusion from this study is that after MARPOL the quantity of litter from marine sources on the study beach has been reduced. It cannot be determined statistically from the data that this is due to compliance with MARPOL Annex V regulations. The author believes from the circumstantial evidence that MARPOL is beginning to have a beneficial effect on the beaches of Texas.

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The Department of the Interior Mission

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering sound use of our land and water resources; protecting our fish, wildlife, and biological diversity; preserving the environmental and cultural values of our national parks and historical places; and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

The Minerals Management Service Mission

As a bureau of the Department of the Interior, the Minerals Management Service's (MMS) primary responsibilities are to manage the mineral resources located on the Nation's Outer Continental Shelf (OCS), collect revenue from the Federal OCS and onshore Federal and Indian lands, and distribute those revenues.

Moreover, in working to meet its responsibilities, the **Offshore Minerals Management Program** administers the OCS competitive leasing program and oversees the safe and environmentally sound exploration and production of our Nation's offshore natural gas, oil and other mineral resources. The MMS **Royalty Management Program** meets its responsibilities by ensuring the efficient, timely and accurate collection and disbursement of revenue from mineral leasing and production due to Indian tribes and allottees, States and the U.S. Treasury.

The MMS strives to fulfill its responsibilities through the general guiding principles of: (1) being responsive to the public's concerns and interests by maintaining a dialogue with all potentially affected parties and (2) carrying out its programs with an emphasis on working to enhance the quality of life for all Americans by lending MMS assistance and expertise to economic development and environmental protection.